VOLUME 2

OPERABLE UNIT FEASIBILITY STUDY FOR MONTGOMERY TOWNSHIP HOUSING DEVELOPMENT SITE

Prepared for:

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION
Division of Hazardous Site Mitigation
Bureau of Site Management
Trenton, New Jersey 08625

DRAFT

July 1987

86C4290

Submitted by:

WOODWARD-CLYDE CONSULTANTS
201 Willowbrook Boulevard
Wayne, New Jersey 07470

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SECTION 1
PROJECT BACKGROUND

INTRODUCTION

The Montgomery Township Housing Development (MTHD) is an approximately 72-acre development located in Skillman, NJ in Somerset County. The development and the immediately abutting area includes eighty-two (82) private homes. In 1979, the residential wells were determined to be contaminated with trichloroethene (TCE). Upon further investigation the wells were found to be contaminated with a number of other volatile organics and several heavy metals, some of which are known or suspected human carcinogens. There are several suspected sources of contamination, which will be addressed as part of the detailed remedial investigation/feasibility study (RI/FS), however, the information to date confirms that contaminated groundwater is the major route of exposure. Thirty-eight (38) of the eighty-two (82) homes have stopped using their wells and are now tied into the Elizabethtown Water Company's water supply distribution system (Searfoss, 1987). The remaining forty-four (44) wells are still in use. In developing the operable unit feasibility study as part of the RI/FS, Metcalf & Eddy has used available background site information and water quality analyses.

AUTHORIZATION

The Montgomery Township Housing Development is ranked at 413 on the National Priorities List (NPL), and, therefore, RI/FS remediation work for this site is federally funded under the Superfund Act of 1980. In 1981, the New Jersey Department of Environmental Protection (NJDEP) entered into a cooperative agreement with the United States Environmental Protection Agency (U.S. EPA), by the authority of Section 104 of Comprehensive Environmental Response Compensation and Liability Act (CERCLA), to manage the Montgomery Township Housing Development RI/FS Project. The NJDEP entered into an agreement with

Woodward Clyde Consultants (WCC), who are conducting the RI/FS work. As a subcontractor to WCC, Metcalf & Eddy, Inc. entered into agreement in May 1987 to complete an operable unit feasibility study of alternative water supplies for contaminated wells at the Montgomery Township Housing Development. Task 1A of WCC's March 1985 proposal to the NJDEP serves as the basis for Metcalf & Eddy's scope of work.

PURPOSE

The purpose of the operable unit feasibility study is to evaluate the need for implementing an alternative water supply and, if the need is positive, to evaluate remedial alternatives for implementation.

SETTING

Drinking water for the Montgomery Township Housing Development is supplied by groundwater sources through private residential wells, and by the privately owned Elizabethtown Water Company. Only thirty-eight (38) of the 77 residents are tied into the Elizabethtown's water supply, and the remaining 39 residents are on private wells. The Elizabethtown Water Company's distribution system is discussed in more detail under Alternative 2 in Chapter 3. The disposal of wastewater for the area is handled by individual septic tanks. Figure 1-1 presents the study area by lot number. The shaded lots represent those homes that are on the Elizabethtown water supply.

The residential wells in the affected area are at an average depth of 125 feet. Based on the available information, groundwater flow in the area appears to be in a northeasterly direction towards the Millstone River.

The affected area as determined in the RI is shown as the shaded section in Figure 1-2. The study boundaries are slightly smaller than this area and are delineated to the north by Montgomery Road, to the south by Montgomery

Township/Rocky Hill borough line, to the west by U.S. Route 206 and to the east by the Millstone River.

Monitoring wells 6D, 11D, 11S, 13D, 13S, 15D representing the local background data associated with this study are indicated as outside of the affected area. The background data used for the operable unit feasibility study is not to be interpreted as regional background groundwater quality but only as local background. For the purpose of the operable unit study the plume is defined by the data generated from the sampling of residential and monitoring wells within the study boundaries.

HISTORY

Concerns about groundwater contamination in Montgomery Township first came about following the discovery of TCE in the well water of the adjacent borough of Rocky Hill, located about one-half mile from MTHD, in 1978. In November, 1979 sampling of the Montgomery Township residential wells was initiated. Concurrently, sampling of wells and septic systems of adjacent businesses was being conducted in order to identify the source(s) of contamination.

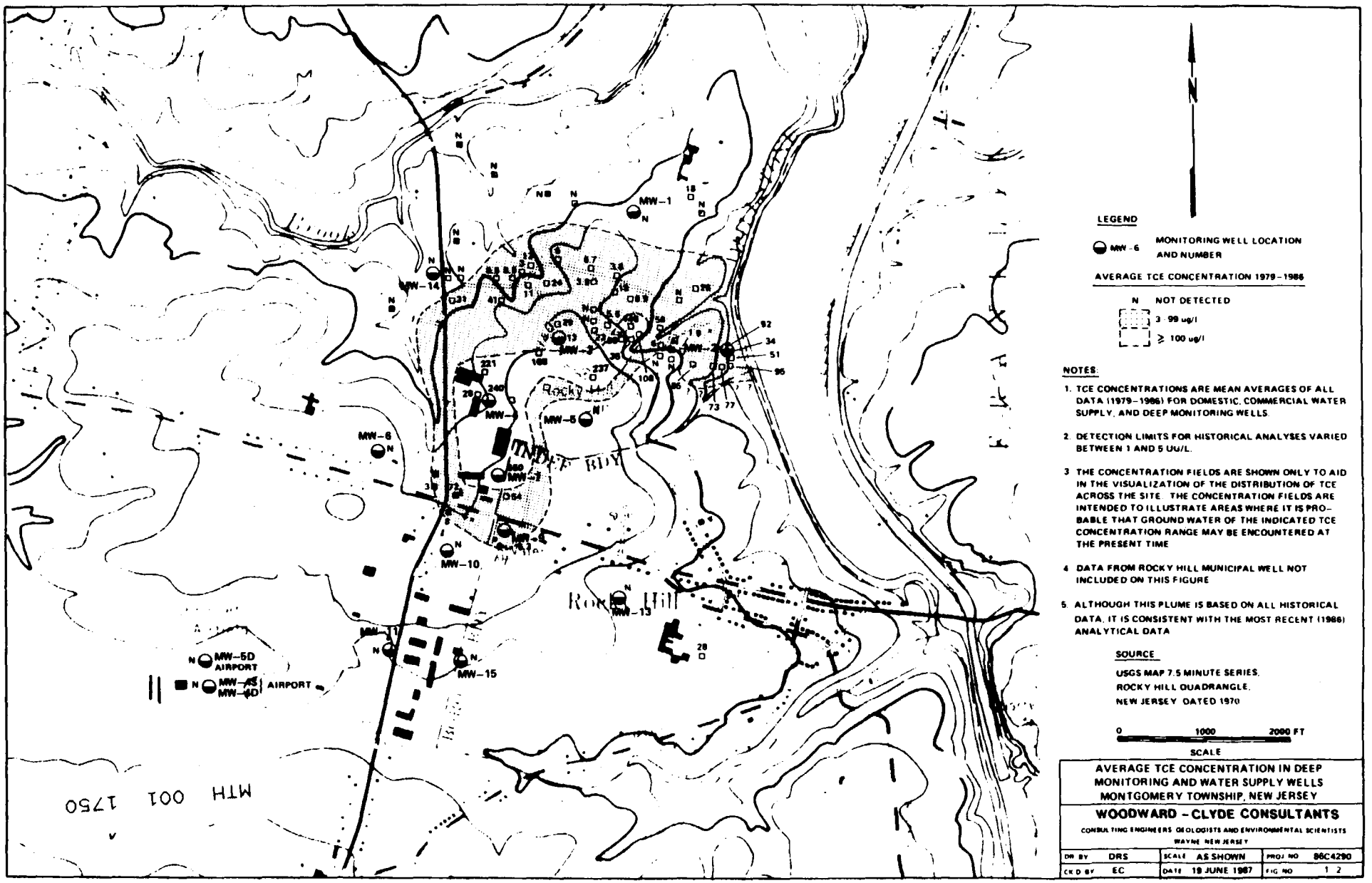
In August of 1980 the NJDEP Bureau of Potable Water advised the Montgomery Township Health Officer that the residents be encouraged to use other sources of water, and that provisions be made for obtaining public water. In 1981 the Elizabethtown Water Company water lines were installed. Since that time, 38 residents in the affected area have chosen to hook up to the Elizabethtown supply. The remaining 39 residents continued to use their well water or to purchase bottled water. One resident had a Culligan activated carbon system installed to treat the well water.

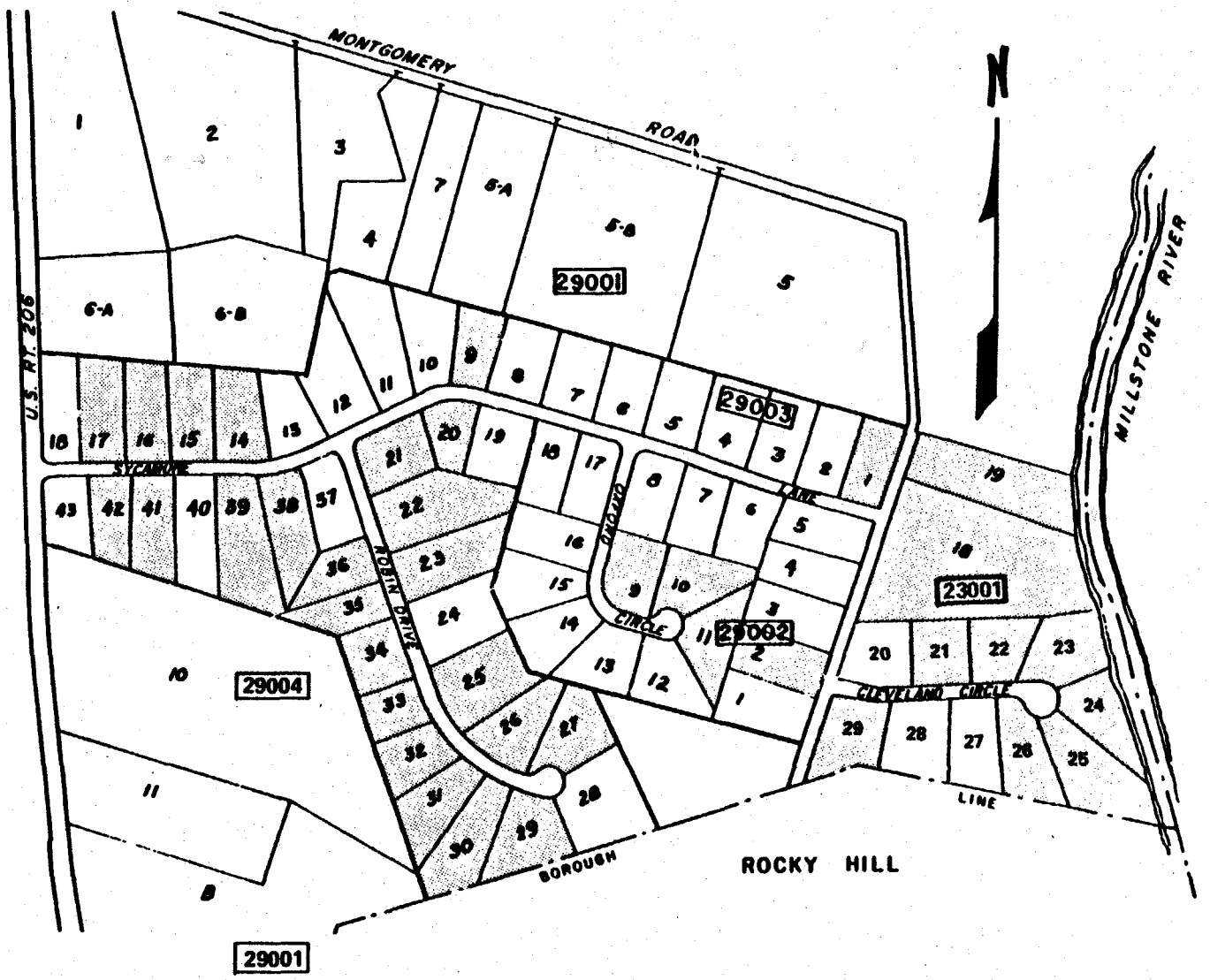
Monitoring

MTH 001 1748

WATER QUALITY ANALYSES

Between November 1979 and June 1986 samples were collected and analyzed for volatile organics or for TCE alone on 18 different occasions. (JACA, 1984; Barg-NJDEP, 1985; Woodward-Clyde Consultants, 1986). TCE was identified at concentrations up to 950 ppb, as well as a number of other volatile organics, including methylene chloride, chloroform, and tetrachloroethene. In 1980, TCE was detected in the well of Princeton Chemical Research, a local company. In 1986 Woodward-Clyde Consultants also sampled and analyzed for metals. Table 1-1 lists all of the contaminants detected in the residential wells and the maximum and mean concentrations at which they were detected in the RI. All of the data for contaminants detected in the residential wells and monitoring wells in the Montgomery Township Housing Development are presented in Appendix B.


MW-1
MW-14
MW-2
MW-5
MW-6
MW-3
MW-10
MW-11
MW-13
MW-15
MW-5D
AIRPORT
MW-4S
MW-4D
AIRPORT
Rocky Hill
LEGEND
MW-6 MONITORING WELL LOCATION AND NUMBER
AVERAGE TCE CONCENTRATION 1979-1986
N NOT DETECTED
3 - 99 ug/l
≥ 100 ug/l
NOTES:
1. TCE CONCENTRATIONS ARE MEAN AVERAGES OF ALL DATA (1979-1986) FOR DOMESTIC, COMMERCIAL WATER SUPPLY, AND DEEP MONITORING WELLS.
2. DETECTION LIMITS FOR HISTORICAL ANALYSES VARIED BETWEEN 1 AND 5 UG/L.
3 THE CONCENTRATION FIELDS ARE SHOWN ONLY TO AID IN THE VISUALIZATION OF THE DISTRIBUTION OF TCE ACROSS THE SITE. THE CONCENTRATION FIELDS ARE INTENDED TO ILLUSTRATE AREAS WHERE IT IS PROBABLE THAT GROUND WATER OF THE INDICATED TCE CONCENTRATION RANGE MAY BE ENCOUNTERED AT THE PRESENT TIME
4 DATA FROM ROCKY HILL MUNICIPAL WELL NOT INCLUDED ON THIS FIGURE
5. ALTHOUGH THIS PLUME IS BASED ON ALL HISTORICAL DATA, IT IS CONSISTENT WITH THE MOST RECENT (1986) ANALYTICAL DATA
SOURCE
USGS MAP 7.5 MINUTE SERIES, ROCKY HILL QUADRANGLE, NEW JERSEY DATED 1970
0 1000 2000 FT
SCALE
AVERAGE TCE CONCENTRATION IN DEEP MONITORING AND WATER SUPPLY WELLS MONTGOMERY TOWNSHIP, NEW JERSEY
WOODWARD - CLYDE CONSULTANTS
CONSULTING ENGINEERS GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS
WAYNE NEW JERSEY
DR BY DRS
CK'D BY EC
SCALE AS SHOWN
DATE 19 JUNE 1987
PROJ NO 86C4290
FIG NO 1 2



SOURCE:
C. SEARFOSS, HEALTH OFFICER,
MONTGOMERY TOWNSHIP.

LEGEND:
PUBLIC WATER CONNECTIONS

RESIDENTS CONNECTED TO PUBLIC WATER
AS OF JUNE, 1987
MONTGOMERY, NEW JERSEY

WOODWARD – CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS
WAYNE, NEW JERSEY

DR. BY:	DRS	SCALE:	1" = 570'	PROJ. NO.:	86C4290
CK'D BY:	EC	DATE:	9 JUNE 1987	FIG. NO.:	1-1

MTH 001 1751

SECTION 2
RESPONSE OBJECTIVES

The operable unit feasibility study precedes the feasibility study for the full remediation of the Montgomery Township Housing Development site. The overall objective of the operable unit feasibility study is to determine a preferred remedial alternative for the contaminated groundwater currently supplied by the private use wells in service within the development. Specifically, the response objectives are:

1) prevention of human ingestion of contaminated residential or municipal groundwater;

2) prevention of human contact with contaminated residential or municipal groundwater; and

3) prevention of human inhalation of contaminated air associated with contaminated residential or municipal groundwater.

The response objectives do not deal with those residences within the development which have previously been connected to the Elizabeth Water Company service. The feasibility study will select and review various alternatives to identify a preferred alternative based on the ability of the alternative to meet the specific response objectives. These objectives are further defined by the consideration of applicable or relevant and appropriate institutional requirements, standards and other criteria to determine the levels which remediation must achieve.

When evaluating a CERCLA site, the Superfund Amendments and Reauthorization Act (SARA) identify applicable or relevant and appropriate requirements (ARARS) as the level to meet with remedial action. To determine the level of clean up to meet with remedial action at the Montgomery Township Housing Development the criteria in Table 2-1 have been compiled.

The criteria presented in Table 2-1 are legally applicable to the hazardous substance of concern or relevant and appropriate under the circumstances of the release or threatened release of the contaminant, and will be used to evaluate the response objectives for the Montgomery Township Operable Unit Feasibility Study. In addition, a third category of health based criteria or advisories have been cited, although they are neither applicable or relevant and appropriate, which will be considered when developing cleanup levels. The following criteria have been included:

- New Jersey Maximum Contaminant Levels (MCL) (A-280 Amendments);
- Federal Maximum Contaminant Levels (MCL);
- Federal Maximum Contaminant Level Goals (MCLG);
- Federal Drinking Water Health Advisories (DWHA); and
- Reference Levels for Carcinogens (calculated).

Criteria normally considered as ARAR's for other hazardous waste sites have not been included here, because this operable unit is limited to private potable well conditions. Criteria pertaining to issues such as groundwater, surface water, and soil cleanups are therefore not incorporated in this discussion. (NJDEP, 1987).

Applicable Requirements

New Jersey Maximum Contaminant Levels (MCLs) were developed under the terms of the State Drinking Water Act, amended in 1984 (A-280 Amendments). The recommendations, if accepted for regulation, will apply to all New Jersey public community water supplies. The MCLs are based on health effects, analytical methodologies and their reliability, and water treatment capabilities. For carcinogens, the MCLs are set at levels which would lead to the development

of cancer in no more than one in one million persons ingesting the contamination over a lifetime, within the limits of medical, scientific and technological feasibility. For noncarcinogens the MCLs are established, within the limits of practicality and feasibility, at levels which will eliminate all adverse physiological effects following ingestion (Sullivan, 1987). The MCLs are published regulations but not yet promulgated. It is fully expected that by the time of remediation these levels will be promulgated and are considered by NJDEP to be applicable requirements for remediation of this site.

The Federal Maximum Contaminant Levels are developed under the Safe Drinking Water Act as enforceable standards for substances in public water supplies. The MCL must be set as close to the MCLG (discussed under 'to be considered' requirements) as is feasible with the use of the best technology, treatment techniques, and other means which are available; while taking cost into consideration. While the evidence indicates that private use wells rather than a public water supply are currently affected, contaminated groundwater migration or future use of the aquifer might result in a contaminated public water supply, therefore this criteria is considered applicable to the action being considered.

Relevant & Appropriate Requirements

None of the selected ARARs fall into the category of relevant and appropriate. All identified levels to meet with remedial action are either applicable or to be considered for this site.

Requirements That Are To Be Considered

Federal Maximum Contaminant Level Goals are promulgated under the Safe Drinking Water Act for public water supplies. An MCLG is a non-enforceable health goal which is set at a level which will result in no known or anticipated health effect with a margin of safety. The MCLGs are to be considered in the development of the response objectives for the site, but as non-enforceable goals

are not applicable or relevant and appropriate requirements. The inapplicability of the MCLGs at the site is consistent with the guidance provided by Mr. Lee Thomas (EPA Administrator) for interpretation of ARARs at Superfund sites. Mr. Thomas' letter of May 21, 1987 is provided in Appendix J.

Drinking Water Health Advisories are non-enforceable advisory levels, developed under the Federal Safe Drinking Water Act, where adverse health effects are not anticipated. The advisory levels presented are those assuming a lifetime exposure. DWHA reference levels for probable and known human carcinogens corresponding to a potential increased lifetime cancer risk of $1x10^{-6}$ are presented in Table 2-1. The DWHA are included to be considered when evaluating the various remedial alternatives, but are not applicable or relevant and appropriate requirements for the Montgomery Township site.

Lastly, reference levels for carcinogens corresponding to a potential increased lifetime cancer risk of $1x10^{-6}$ can be calculated from cancer potency factors found in the Superfund Public Health Evaluation Manual (USEPA, 1986). These values have been calculated where possible and are useful to be considered for evaluating the various remedial alternatives presented.

No single set of Federal or State criteria dictate acceptable concentrations in drinking water for all of the contaminants detected in residential and monitoring wells at and near the Montgomery Township Housing Development. For this reason all ARARs and criteria to be considered have been reviewed and summarized in the final two columns of Table 2-1. These columns present the most stringent site-specific ARAR to be used in the feasibility study and the selected site-specific health based goals to be considered.

TABLE 2.1 CRITERIA REVIEWED FOR RESPONSE OBJECTIVES(a)

Substances	NJ MCL (A-280) (ug/l)(b)	MCL(c) (ug/l)	MCLG(d) (ug/l)	Health Advisories (ug/l)(e)	Reference Levels for Carcinogens (ug/l)(f)	Site-Specific ARAR (ug/l)(g)	Site-Specific Goal to be Considered (ug/l)(h)
Tetrachloroethene	1		(l)	0.7(q)	0.69	1	0.69
Ethylbenzene			680(p)	680			680
Chloroform		100(m)			0.43	100	0.43
Chlordane	0.5		0(p)	0.0218(q)	0.022	0.5	0
Toluene			2,000(p)	10,100			2000
Carbon Tetrachloride	2	5(p)	0	0.3(q)	0.27	2	0
1,1-Dichloroethene(-ethylene)	2	7(p)	7	0.24(q)	0.06	2	0.06
1,2 Dichloroethane	2	5(p)	0	0.95(q)	0.38	2	0
Trichlorofluoromethane							
Bromodichloromethane(THM)		100(m)				100	
1,1 Dichloroethane							
1,1,1 Trichloroethane	26	200(p)	200	22,000(q)		26	200
Trichloroethene(-ethylene)	1	5(p)	0		3.2	1	3.2
Methylene Chloride	2			5(q)		2	5
Acetone							
Diethylphthalate							
Trans-1,2-Dichloroethene(-ethylene)	10		70(p)	350		10	70
O-Dichlorobenzene	600		620(p)	3,125		600	620
1,2,4-trichlorobenzene	8					8	
N-Butylbenzene							
2,3 Benzofuran							
Cyclopropylbenzene							
N-Nitrosodiphenylamine							
Bis(2 ethylhexyl)phthalate(t)					51		51
Di-n-butylphthlate							
Phenol							
Aluminum							
Arsenic			50(p)	50	0.002		0.002
Barium		50(m)	1,500(p)	1,800			1,500
Beryllium		1,000(m)			NA	50	
						1,000	

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TABLE 2.1 (Continued). CRITERIA REVIEWED FOR RESPONSE OBJECTIVES(a)

Substances	NJ MCL (A-280) (ug/l)(b)	MCL(c) (ug/l)	MCLG(d) (ug/l)	Health Advisories (ug/l)(e)	Reference Levels for Carcinogens (ug/l)(f)	Site-Specific ARAR (ug/l)(g)	Site-Specific Goal to be Considered (ug/l)(h)
Cadmium		10(m)	5(p)	18	NA	10	5
Calcium							
Chromium		50(m)(s)	120(p)	170	NA	50	120
Cobalt							
Copper			1,300(p)				1300
Iron							
Lead		50(m)	20(p)	10(k)		50	10
Magnesium							
Manganese							
Mercury		2(m)	3(p)	5.5		2	3
Nickel				350	NA		350
Potassium							
Silver		50(m)				50	
Sodium							
Thallium							
Vanadium							
Zinc							
Cyanide				750			750

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TABLE 2.1 (Continued). CRITERIA REVIEWED FOR RESPONSE OBJECTIVES(a)

NOTES:

a. Federal and State criteria reviewed to prepare this table.
b. Maximum Contaminant Level, State Safe Drinking Water Act.
c. Maximum Contaminant Level, Federal Safe Drinking Water Act.
d. Maximum Contaminant Level Goal, Federal Safe Drinking Water Act.
e. EPA drinking water health advisories, based on life time exposure.
f. The reference level for carcinogens is calculated based on a 1×10^{-6} risk and the cancer potency factor (CPF) in Superfund Public Health Evaluation Manual (USEPA, 1986) as follows:

$$\text{reference concentration (ug/l)} = (1 \times 10^{-6})/\text{CPF}$$

Where available oral route CPFs are used, same reference concentrations are based on inhalation route CPFs.
g. Most stringent site specific applicable or relevant and appropriate requirement.
h. Most stringent health-based goal to be considered for action being considered.
i. An MCLG was proposed but subsequently withdrawn, a new MCLG currently under discussion (USEPA, ODW, 1987).
j. DEHP included as per input from NJDEP.
k. Based on Health Advisory of 20 ug/day and ingestion of 2 liters per day.
m. Interim MCL.
p. Proposed value.
q. Reference concentrations for potential carcinogens, corresponds to a potential cancer.
r. Di(ethylhexyl)phthlate or Bis(2-ethylhexyl)phthlate.
s. Value of Chromium(+6).
NA Not available.

SECTION 3
PUBLIC HEALTH ASSESSMENT

INTRODUCTION

The Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) enacted by Public Law 96-510, December 11, 1980, as amended by PL 99-499, October 17, 1986 (SARA), authorizes the United States Environmental Protection Agency (USEPA) to take actions in response to an actual or threatened release of hazardous substances. Section 106(a) of CERCLA states "...When the President determines that there may be an imminent and substantial endangerment to public health or welfare or the environment because of an actual or threatened release of a hazardous substance from a facility, he may ... secure such relief as may be necessary to abate such danger and threat ..." The public health assessment provides justification and documentation of any such danger and/or threat to human health so that appropriate remedial measures can be selected for the site.

Initially potential health effects are investigated with respect to the no action alternative. Potential increases or decreases in risks associated with each of the other alternatives will follow the no action alternative.

The assessment is presented in four parts, identification of indicator chemicals, toxicity profiles, exposure assessment and risk characterization. The assessment is restricted to the Montgomery Township Housing Development and exposure to contaminated groundwater.

IDENTIFICATION OF INDICATOR CHEMICALS

Development of a list of indicator chemicals is the first stage in the characterization of risk. The indicator chemicals for the Montgomery Township

Housing Development study were selected in two major steps in a manner consistent with EPA guidance (USEPA, 1986b). First, the chemicals identified at the site were tentatively ranked utilizing a scoring system defined in EPA guidance manuals. Final selection was then based on professional judgement following a more comprehensive review of physical and chemical characteristics and the site-specific tentative rankings. Information reviewed during the indicator chemical selection process is summarized in Appendix H, Tables H-1 through H-4.

The Superfund Public Health Evaluation Manual (USEPA, 1986b) provides guidance regarding a ranking system for use in selecting indicator chemicals. The selection process is designed to identify the "highest risk" chemicals at a site so that the public health evaluation is focused on the chemicals of greatest concern.

The selection process calculates C (concentration) times T (toxicity) (CT) for each media for each appropriate exposure route. The CT values for each media are summed to determine IS, the indicator score. For this study, a single media, single exposure route calculation was conducted: water, oral. Therefore, the CT value equals the IS. Table H-4 in Appendix H provides the detailed results of the tentative chemical ranking with chemicals ranked separately for potential carcinogen (PC) and noncarcinogen (NC). Once a temporary ranking is determined the indicator chemicals are finalized by the consideration of chemical and physical properties of the individual chemicals. Parameters such as relative prevalence of PC and NC chemicals at the site, water solubility, vapor pressure, Henry's Law constant, and organic carbon partition coefficient (Koc). Tables H-2 and H-3 present a summary of these parameters for the indicator chemicals selected.

SARA established the requirement for the preparation of a list of hazardous substances found at National Priority List (NPL) hazardous wastes sites (in order of priority), toxicological profiles of each of the substances and a research program to fill data gaps. The first 100 priority list substances were identified in

the Federal Register in April 17, 1987 (Fed. Reg., Vol 52, No. 74, pg. 12866) as additional guidance in conducting risk assessments for CERCLA sites. The list of 100 substances was broken down into four groups with the highest priority substances in Group 1. Inclusion on the priority list was based on chemical toxicity, frequency of occurrence at NPL sites or other facilities, and potential for human exposure to the substances. The potential for human exposure was based on the frequency of occurrence in groundwater and surface water at NPL sites. For each of the chemicals detected at the Montgomery Township site its ranking in the USEPA priority groups was considered. Maximum and mean concentrations of contaminants, frequency of occurrence in groundwater samples, ARARs and carcinogenic weight of evidence were also reviewed. These parameters are summarized in Table H-1. The indicator chemicals listed below were selected after following the selection process described above. Ten (10) chemicals were ultimately selected including organic and inorganic compounds. The indicator chemicals are:

Trichloroethene
Tetrachloroethene
Chlorodane
Arsenic
Barium
Beryllium
Chromium
Lead
Nickel
Silver

TOXICITY PROFILES

The transport of contaminants in groundwater and the eventual fate of the contaminants in the environment are governed by complex interactions with the physical, chemical and biological environment. Following migration in the

environment, human exposure to contaminants may cause health effects. In this section, physical and chemical properties of the indicator chemicals and toxicological profiles are presented to assist in understanding how contaminants migrate in the environment, what the potential health effects are, and why the environmental and health criteria are set at their current levels.

Chemical and Physical Properties

The chemical and physical properties of the selected indicator chemicals are directly related to their transport and fate in the environment. In addition, these properties have a direct impact on how the indicator chemicals will behave when introduced to life forms. These impacts include bio-magnification, bio-accumulation and metabolization.

The indicator chemical properties and distribution coefficients are presented in Appendix H, Tables H-2 and H-3. Fate and transport as well as primary uses are discussed below.

Trichloroethene is a solvent for fats, waxes, resins, oils, rubber, paints and varnishes. It is also used in dry cleaning and in degreasing. Trichloroethene rapidly volatilizes into the atmosphere where it reacts with hydroxyl radicals to form new compounds. This is the most important transport and fate of trichloroethene in soils and water; however, it does migrate into the groundwater rapidly. There is some evidence that higher organisms can metabolize trichloroethene (Clements, 1985).

Tetrachloroethene is used in dry cleaning, metal degreasing, and as a chemical intermediate in the production of freon. Tetrachloroethene rapidly volatilizes into the atmosphere where it reacts with hydroxyl radicals to produce new compounds, this is the most important transport and fate process of tetrachloroethene. It also leaches into groundwater readily. There is some evidence that higher organisms can metabolize tetrachloroethene (Clements, 1985).

Chlorodane was used as an insecticide, but is now banned due to persistence in the environment. Chlorodane resists chemical and biological degradation but can be volatile. Certain food and feed crops accumulate chlorodane residues in soil and oxychlordane has been found in human adipose tissue and human milk samples (Clements, 1985).

Arsenic is used in copper hardening, glass manufacturing, radioactive tracers and insecticides. The oxidation state, and chemical specification will determine the distribution and mobility of arsenic in the environment. In general, arsenic is very mobile in the environment but does not appear to bioconcentrate (Clements, 1985).

Barium mined from the earth as barite or barium sulfate is primarily used in the manufacture of ground barite which in turn is used in the drilling of oil and gas wells. A secondary use for barite is in the paint and rubber industries where it is used as a paint pigment (Clayton, 1982). As a pure chemical barium is extremely reactive, readily decomposing in water. In the aquatic environment, barium has a limited solubility (usually not more than a few parts per million) because it readily forms a precipitate with insoluble carbonate and sulfate salts. In the atmosphere, barium can be transported in the form of particulates. Bioaccumulation of barium does not occur to a significant extent (Clements, 1985).

Beryllium is a neutron source, neutron reflector and moderator in nuclear reactors, radio tubes and aerospace structures. Most beryllium compounds are readily soluble in water; however, beryllium hydroxide can form from beryllium salts. It is suggested that beryllium absorbs onto clay and is present in the environment primarily in sorbed or precipitated, rather than dissolved form. There is no evidence of beryllium transfer through the food chain but it can accumulate to a slight extent in aquatic organisms (Clements, 1985).

Chromium is contained in paint and pigments, used in plating, steel manufacturing, and leather tanning. Chromium is quite soluble and is not sorbed

to any significant amount by clays or hydrous metal oxides. Chromium is also very mobile in the aquatic environment and groundwater. Little is known about chromium bioaccumulation in organic compounds. However, absorbed chromium in plants remains in the roots and not in the leaves (Clements, 1985).

Lead is used in tank and pipe linings, and in the manufacturing of sulfuric acid, petroleum refining, x-ray and atomic radiation protection, and in wide use as an alloy in various products. Lead transport in the atmosphere occurs more rapidly than in soil or aquatic environments and does not appear to biomagnify through the food chain (Clements, 1985).

Nickel. The largest use of nickel is in the manufacturing of monel metal, stainless steels, and nickel-chrome resistance wires. Nickel is estimated to have a long life time in the atmosphere. The aquatic and soil fate of nickel depends upon ion exchange and concentrations of iron and manganese oxides which sorb nickel (EPA, 1984). Many nickel compounds are highly water soluble, resulting in high water solubility, however at high pH, precipitation can occur (Clement, 1985).

Silver is used in coins, table ware, mirrors, jewelry and ornaments through electroplating. In addition, it has been used to purify water because of its' toxicity to bacteria. Sorption of silver in the environment occurs primarily by manganese dioxide, ferric hydroxide, and clay minerals. In general, concentrations of silver are higher in bed sediments of lakes rather than overlying waters. Bioaccumulation of silver by aquatic plants, invertebrates and vertabrates occurs readily. Little food chain magnification seems to occur (Clements, 1985).

Toxicological Properties

The toxicological properties of indicator chemicals are based on a literature review which included a review of Health Effects Assessment Documents developed by the USEPA Environmental Criteria and Assessment Office (USEPA,

1984) and the Integrated Risk Information System from the USEPA Office of Research and Development (USEPA, 1986). Chronic toxicity, target organs, reference doses, carcinogenic potency, as well as other information suggested in the New Jersey Draft Risk Assessment Guidelines for Hazardous Waste Sites, (NJDEP, 1986), are included for each of the indicator chemicals.

Trichloroethene. Acute inhaled exposures to trichloroethene causes central nervous system (CNS) depression. Historically, trichloroethene was used as a general anesthetic. Acute oral toxicity in several animal species have ranged between 6000 and 7000 mg/kg (Clements, 1985). Chronic human exposures have typically been via inhalation. The threshold limit value (TLV) is currently 50 ppm (USDHHS, 1985). Occupational exposures of 5 to 15 years at levels below the TLV have shown evidence of increased nervous system disorders (USEPA, 1980). Industrial use of trichloroethene has been associated with dermatological problems. However, no such problems have been reported with exposures to dilute aqueous trichloroethene solutions. Trichloroethene has not been shown to be teratogenic, and the lab-grade reagent which tested with positive mutagenic results was contaminated with two compounds known to be mutagenic (USEPA, 1984e).

Using the classification system suggested by the Carcinogen Assessment Group of the U.S. EPA, trichloroethene is classified as a B2 - Probable Human Carcinogen. Human data is inadequate, and while there have been some positive and negative animal studies, oral and inhalation exposure in mice have caused hepatacellular carcinogenic responses (USEPA, 1980). A reference dose level of 7 ug/kg/day has been developed based on a two-year feeding study in rats, ingestion of two liters of water per day and a 70 kilogram body weight (ICAIR, 1985).

Tetrachloroethene. No human chronic oral data is available for tetrachloroethene. A bioassay conducted for exposure to tetrachloroethenes in corn oil by gavage resulted in toxic nephropathy with the lowest observable

adverse effect levels (LOAEL) for mice at 300 mg/kg/day and for rats at 471 mg/kg/day. The same bioassay showed increased hepatacellular carcinoma in mice exposed to tetrachloroethene (396 mg/kg/day for female mice and 536 mg/kg/day for male mice). No increased cancer rate was seen in exposed rats (USEPA, 1984d). A reference dose level (RFD) of 2×10^{-2} mg/kg/day is defined by a NOAEL of 19.4 mg/kg/day in a chronic inhalation study using rats (USEPA, 1986a). Tetrachloroethene is considered a probable human carcinogen (Group B2). The USEPA recommended oral potency factor is 5.1×10^{-2} $(mg/kg/day)^{-1}$ which is based on tumor incidence in female mice. The carcinogenic potency factor for inhalation exposures is 1.7×10^{-3} $(mg/kg/day)^{-1}$ (USEPA, 1986b).

Tetrachloroethene is absorbed through the gastrointestinal tract and the lung. Studies of dogs have shown that intestinal absorption is facilitated by fats and oils (USEPA, 1984d). Inhalation is the principal route by which tetrachloroethene enters the human body with absorption readily occurring through pulmonary alveolar air (USEPA, 1985). The threshold limit value for tetrachloroethene is 50 ppm (USDHHS, 1985). The target organs include the upper respiratory system, liver, kidneys, eyes, and central nervous system (USDHHS, 1985).

Chlorodane. Originally manufactured as a pesticide, chlorodane has been banned due to its persistence and toxic effects in the environment. The subchronic effects on experimental rats of ingested chlorodane at concentrations of 160 mg/kg for 400 days included increased liver weights, and decreased body weight gain (USEPA, 1984). Intracytoplasmic bodies in the liver also developed and at higher doses, vacuolization and enlarged liver nuclei were seen (USEPA, 1984). In addition, benign proliferative lesions in the liver of experimental mice were seen when the mice ingested 25-50 ppm for a 36 week period (Becker, 1979).

Pertinent data regarding subchronic toxicity of inhaled chlorodane is not available. However, the threshold limit value (TLV) for chlorodane is currently

0.5 mg/m^3 (USDHHS, 1985). The National Institute for Occupational Safety and Health (NIOSH) lists the Central Nervous System (CNS), eyes, lungs, liver, kidneys and skin as target organs of exposure. Exposure routes include inhalation, ingestion, contact and absorption (USDHHS, 1985).

The chronic effect of chlorodane on rats exposed to a 5-300 mg/kg diet for two years included tremors, liver and kidney hypertrophy, and histopathology in the liver, kidney, lung, myocardium, adrenal gland and spleen (USEPA, 1984). It was observed during these experiments that female rates were more sensitive to chlorodane than male rats, as evidenced by increased mortality in females. A chronic no observable effect level (NOEL) for dogs exposed orally to chlorodane is 3 mg/kg diet (USEPA, 1984). The RFD is 0.05 ug/kg/day (USEPA, 1986b).

Acute oral exposure to chlorodane in humans causes central nervous system (CNS) toxicity including, but not limited to, irritability, salivation, labored respiration, muscle tremors, convulsions and death. Chlorodane can cross the placenta and chlorodane metabolites are found in milk. Chlorodane is classified as a Group B2 carcinogen by the Carcinogen Assessment Group. The oral carcinogen potency factor is 1.61 $(mg/kg/day)^{-1}$ (USEPA, 1986b).

Occupational exposure to inhaled chlorodane has been related to asplastic and refractory megoblastic anemia, as well as acute stem cell, acute lymphoblastic and acute myelomonocytic leukemia (USEPA, 1984). A retrospective mortality study of workers employed in the manufacture of chlorodane and heptachlor indicated that observed incidences of all types of cancer, except lung cancer, were not statistically significant (USEPA, 1984).

Arsenic. The subchronic oral toxicity of arsenic in dogs was studied using both sodium arsenate and sodium arsenite. The sodium arsenite proved to be more toxic than sodium arsenate using concentrations in diets from 0, 5, 25, 50 and 125 mg/kg/day. The no observable effect level (NOEL) was 50 mg diet for both sodium arsenate and sodium arsenite (USEPA, 1984a). Studies performed on mice

while administering up to 5 mg/day of arsenic throughout pregnancy showed no observable effect on offspring (USEPA, 1984a).

Human studies of persons who ingested arsenic in antiasthmatic herbal preparations intermittently for periods ranging from 6 months to 15 years at an estimated 2.5 mg/day as arsenic (III) oxide or 10.3 mg/day as arsenic sulfide was performed in Singapore. The effects of exposure included internal malignancies, generalized hyperpigmentation, hyperkeratosis of palms and soles, multiple arsenical keratoses, sensorimotor polyneuropathy, fine finger tremors, chronic headaches, insomnia, gastritis and anemia (USEPA, 1984a).

Studies have shown acute toxicity from inhalation of gaseous arsenic compounds can result in skin lesions, cardiovascular and respiratory effects, and peripheral neuropathy. No adequate human exposure information is available for any of these studies (USEPA, 1984a).

The chronic oral toxic effects of arsenic observed in humans includes skin lesions, peripheral vascular disease, peripheral neuropathy and black foot (a peripheral circulatory disease characterized by gangrene of the extremities). A study performed on persons consuming arsenic contaminated drinking water in Taiwan established a no observable effect level (NOEL) of 0.017 mg/l for black foot disease (USEPA, 1984a).

A study performed on workers of a smelting facility who were exposed to atmospheric arsenic concentrations which ranged from 100 to 5000 ug/m^3 showed that exposure to arsenic in the workroom was strongly correlated with excess mortality due to respiratory cancer (USEPA, 1984a). The current threshold limit value (TLV) for arsenic is 0.2 mg/m^3 (USDHHS, 1985).

Inorganic arsenic is classified as a Group A compound (human carcinogen) by the Carcinogen Assessment Group of the U.S. EPA based on evidence of skin and lung cancers in humans exposed to inorganic arsenic compounds. The oral

carcinogenic potency factor for arsenic is 15 $(mg/kg/day)^{-1}$ based on the assumption that humans drink 2 liters of water per/day (USEPA, 1984a).

Barium. Laboratory tests on male and female rats have shown that inhalation of barium carbonate has an effect on gametogenesis and on the reproductive organs. Soluble barium compounds are toxic in human by ingestion or inhalation. Acute barium poisioning results in a prolonged stimulant action on the muscle. Fatal does to humans for barium carbonate and barium chloride have been established at 57 mg/kg and 11.4 mg/kg, respectively (Clements, 1985). Barium and associated compounds have an acceptable intake for oral chronic exposure (AIC) of 5.10E-2 mg/kg/day (established by HEA).

Beryllium. Dermal exposure to soluble beryllium compounds, primarily a result of occupational exposures, can cause contact dermatitis. One of the earliest observed effects of beryllium toxicity is the development of rachitic bones. Studies performed in rats have shown some beryllium accumulation in the skeleton and liver after exposure (USEPA, 1980).

Rat studies have shown that the amount of beryllium retained after ingestion was small (0.006 percent). Other studies have shown rats feces contain 60 to 90 percent of beryllium after ingestion (USEPA, 1980).

Intravenous beryllium is highly toxic to animals in small doses. The LD_{50} for rats was reported to be 0.44 mg/kg after being injected with soluble beryllium salts. However, the toxicity to similar rats was reduced when the same concentrations of beryllium was ingested. The oral LD_{50} was reported to be 9.7 mg/kg (USEPA, 1980). An RFD of 0.5 ug/kg/day is listed for beryllium given an oral exposure (USEPA, 1986b).

The major toxicological effects of beryllium are on the lung. Acute diseases have occurred in humans following inhalation of highly soluble beryllium salts at concentrations below 100 ug/m^3 (USEPA, 1980). The respiratory effects have

included rhinitis, pharygitis, tracheobronchitis and acute pneumonitis. In humans, increased levels of beryllium have been reported in the lymph nodes and lungs more than 20 years after termination of occupational exposures.

Beryllium is considered a B1 carcinogen (probable human carcinogen) via inhalation due to excess lung cancers noted in past studies. Beryllium has also been reported to induce chromosomal and mitotic abnormalities in cell cultures (EPA, 1980). The carcinogenic potency factor for inhalation exposures is 4.86 $(mg/kg/day)^{-1}$ (USEPA, 1986b).

Teratogenicity data on beryllium is limited. However, it is reported to inhibit the embryonic development of snails and salamanders (USEPA, 1980).

Chromium. The toxicity of chromium is greatly effected by its ionic state and chemical form. Hexavalent chromium, for example, is more toxic then trivalent chromium. Most of the toxicity data on chromium Cr(+6) is from occupational studies where perforated nasal septa and ulcerations in humans were observed at airborne concentrations of 0.1 - 5.6 mg/m^3 were noted. Dermatitis resulting from chromium exposure has also been observed. In some cases, these health effects were seen after less than one year of exposure.

There are no human data available on the chronic toxicity of chromium by ingestion. A study of dogs exposed to 0.089 mg/kg/day of Cr(+6) through drinking water was identified as a no observable effect level (NOEL). Chronic exposure to 1467 mg/kg/day of Cr(+3) in rats resulted in no effects. Other chronic studies resulted in health effects including atrophy of the spleen and liver, and atrophy of pulmonary bronchi, producing emphysemic like changes. There is no indication that Cr(+3) is carcinogenic to humans, but Cr(+6) is considered a Group A human carcinogen based on evidence of respiratory carcinogenicity in occupationally exposed persons during chromate production. The carcinogenic potency factor for inhaled exposures is 41.0 $(mg/kg/day)^{-1}$ (USEPA, 1986b). The water standard is not set to protect against carcinogenicity due to the assumption that Cr(+6) would

be reduced in the gastrointestinal tract to Cr(+3), thus minimizing exposure to the Group A carcinogen (USEPA, 1984).

Lead. It has been established that 8% of the lead ingested daily by humans is absorbed (USEPA, 1984). Age has a major influence on the extent of lead adsorption. It was observed that absorption of lead in infant rats was considerably greater than in adults. Similar results have been observed in humans (USEPA, 1984). The available evidence suggests that effects of lead on the formations of hemoglobin and other hemo-protein are detectable at lower levels of lead exposure than are effective on any other organ system. Chronic exposure to low levels of lead can cause subtle learning disabilities in children. Neurological effects in children appear to be a sensitive indicator of lead toxicity (USEPA, 1984). The threshold for decreased hemoglobin levels in blood is 0.4)g/ml while that for noticeable brain disfunction in children is estimated at 0.5)g/ml (USEPA, 1984).

No studies indicating a teratogenic effect of orally administered lead for humans were located in the available literature. However, rat studies have shown a delay in birth, and excessive mortality among the offspring weaning (USEPA, 1984).

During lead inhalation studies of rats, high doses have lead to abortions. In British women, occupational exposure lead to miscarriages (USEPA, 1984).

Data concerning the carcinogenic potential of lead to humans after oral exposure is inconclusive (Clements, 1985). However, deaths due to all malignant neoplasms were increased among lead smelter workers. In addition, there is evidence that several lead salts are carcinogenic in mice and rats, causing tumors of the kidneys after either oral or parental administration (Clements, 1985). Since humans are not environmentally exposed to the lead salts associated with tumors in animals, lead and lead compounds are most appropriately classified as a Group C possible human carcinogen (USEPA, 1984).

The target organs for lead include the gastro intestinal tract, central nervous system, kidneys, blood, and gingival tissue (USDHHS, 1985).

Nickel. The toxicity of nickel is greatly affected by its ionic state and chemical form. Certain nickel compounds appear to be more toxic than others. There are no available data concerning the toxicity of nickel to humans by ingestion. There are however, a number of subchronic and chronic animal studies that examined oral exposure to nickel. In a six-week study of weanling rats, a no observable effect level (NOEL) was determined to be 10 mg/kg/day of nickel in the form of nickel acetate (USEEPA, 1984b). At higher doses, effects observed were decreased body weight and hematological changes including reduced iron content in red blood cells. There are no available data concerning the teratogenicity or mutagenicity of nickel by ingestion. Inhaled exposure to nickel as nickel carbonyl has proven to be teratogenic. Epidemiological studies have associated airborne nickel exposures with nasal cavity and lung cancers (USEPA, 1984b). Nickel is classified as a Group A carcinogen for inhaled and oral exposures. The carcinogenic potency factor for the inhalation exposure route is 1.19 $(mg/kg/day)^{-1}$ (ICF, 1986). The RFD for nickel for oral exposure is 10 ug/kg/day (ICF, 1986b). Contact with nickel and nickel compounds can lead to dermal sensitization (Clement, 1985).

Silver. One of the most physically cumulative and also the most physiologically cumulative of the elements, silver can lead to a disturbing, permanent cosmetic effect called argyria, where the body burden has accumulated silver in excess of one gram (Clayton, 1981). Although silver bio-accumulates, metabolic factors such as low efficiency of absorption through the skin, lungs, and gastro-intestinal tract reduce the probability of adverse exposure (USEPA, 1981).

The most significant human exposure, in terms of amount, to silver is its medicinal use in topical preparations where daily medicinal exposure levels c 50 mg/day which may occur during treatment of severe, widespread burns. The duration of this form of exposure and the size of the exposed subpopulation is

small. Almost all other individual exposure routes occur at levels at least three orders of magnitude lower than this treatment exposure.

There is no human data on silver exposure which suggests it to be carcinogenic. However, rats have been observed to produce tumors after silver implantations. These tumors were observed to be localized at the silver implantation area only (EPA, 1981).

The lowest reported lethal dose of silver to humans is very high at 10 grams taken orally in the form of silver nitrate. This level cannot be directly compared with effects concentrations for silver ion alone because the toxicity of silver nitrate is partially attributed to its caustic properties. The no observable effect level (NOEL), based on a large fraction of the U.S. population, for silver in drinking water is 0.13 mg/day (EPA, 1981).

EXPOSURE ASSESSMENT

This operable unit feasibility study is focused on contaminated groundwater at the Montgomery Township Housing Development residential wells. Potential exposure pathways to humans from use of the water from the wells include:

- o Ingestion of groundwater;
- o Inhalation of volatile chemicals released during water use; and
- o Direct dermal contact with contaminated water.

Human exposures to contaminated groundwater has routinely focused on exposure by ingestion. Recently, studies have indicated that exposures to volatile chemicals by inhalation may be as large or larger than the ingestion exposure (Andelman, 1985; Foster, 1986; Dixon et al., 1985). Dermal exposures are also being investigated. Work by Foster and Chrostowski indicated that dermal absorption exposure contributes less than one percent total exposure when including estimates of ingestion, inhalation and dermal exposures. Other work has

indicated that dermal route exposure are more significant (Shehata, 1985 and Brown et al., 1983).

Persons at risk of exposure to the contaminants in groundwater include those persons still using their residential wells. A total of 39 private residences in the Montgomery Housing Development are currently not connected to the public water supply. Census data for the census tract containing the Montgomery Township Housing Development (Somerset County Building, 1987), shows that there are an average 3.07 persons per household in this tract. The percentage of persons zero to five years and five to seventeen years is 4.6 and 23.3 percent respectively. This indicated there are approximately 120 persons using the wells at the 39 residences not connected to the public water supply, and that there are approximately six children between the ages of zero and five and 28 persons between the ages of 5 and 17. The housing development is primarily single family dwellings. There are no schools, hospitals or convalescent homes in the development.

Exposure and dose are estimated for exposure by ingestion, inhalation and dermal contact. Exposures to children and adults are investigated.

Ingested dose (IG) is calculated as:

$$IG = (Cw)(Vw) \cdot BW$$

where Cw is the concentration in water, Vw is volume of water ingested per day and BW is body weight.

The inhaled dose (IH) is calculated as:

$$IH = (Ca)(Va) \cdot BW$$

where Ca is the concentration of the contaminant in air, Va is the volume of air inhaled and BW is body weight. The concentration of volatile chemicals in air, from home use of contaminated water, was calculated using the method described in work by Andelman (1985 and 1987).

Concentration in air, assuming 50 percent volatilization of chemicals, is calculated as:

$$Ca = 0.3\ Cw$$

The proportionality constant, 0.3 L/m^3, developed by Andelman incorporates an air mixing factor, a rate of exchange with outdoor air, and a water use by a family of four in a typical home (Andelman, 1986). The fraction of chemicals moving from water to air is a function of individual chemical properties and water use. It has been suggested that those chemicals with a Henry's Law constant of greater than 2.3×10^{-6} atm - m^3/mole be considered for exposure by inhalation (Andelman, 1985). Exposure by inhalation will be calculated for trichloroethene, tetrachloroethene, and chlorodane.

While a high percentage of volatilization is expected during a hot shower, a lower proportion of chemicals are likely to be volatilized from other water use. An average volatilization of 50 percent in a typical North American home has been suggested as realistic for a simple screening model (Andelman, 1987).

The dermal dose (DD) from direct contact and absorption through skin is estimated as:

$$DD = \frac{(Cw)\ (SA)\ (F)\ (\text{permeability constant})\ (t)}{BW}$$

where SA is the body surface area, F is the fraction of the surface area expose during bathing, the permeability constant is held constant as 0.001 l/cm^2 hr, and

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is the duration of bathing. The permeability constant is chemical specific, since adequate quantification of skin absorption rates are not available in the literature, an average, determined by Brown et al. for four volatile organic chemicals was utilized. This same approach has been used by others estimating dermal dose from exposure to chlorinated hydrocarbons (Foster, 1986).

Estimates of human dose from dermal contact and absorption is included for the organic indicator chemicals.

Exposure to metals from inhalation and dermal absorption is not included when calculating dose. As was mentioned previously, compounds with high Henry's Law constants are expected to result in significant inhalation exposures (Andelman, 1985). It has been suggested in the literature that chemicals with high octanol/water coefficients might also have high permeability constants for human tissue (EPA, 1979). Since Henry's Law constants and octanol/water coefficients are not available for the metals investigated, exposure to metals by ingestion is the only route evaluated.

Total human dose (TD) is calculated as:

$$TD = IH + IG + DD$$

The following parameters are used to calculated dose:

	Child	Adult
Body weight (kg)	10	70
Water ingestion rate (l/day)	1	2
Volume of air inhaled (m^3/day)	8	20
Body surface area (cm^2)	4,000	18,000
Fraction of body in bath	0.75	0.80
Baths each week	7	3

It is assumed that adults take baths three times a week, while young children who are unlikely to shower, are bathed once a day.

Estimates of human dose from exposure to contaminants in groundwater at the Montgomery Housing Development are presented in Tables 3-1 through 3-3. A realistic worst case is calculated using the maximum concentration of the contaminant detected in groundwater during the remedial investigation. A more probable dose is calculated from the mean of concentrations detected in the sampling of residential and monitoring wells. When the contaminant was not detected, the contract detection limit was used to calculate the average. The plume or affected area has been identified in the remedial investigation and is indicated in Figure 1-2. Exposure and dose are based on contamination within the identified plume area. To put this level of contamination and the calculated dose into perspective, dose was also calculated assuming exposure to compounds and metals in the background wells (MW-6D, MW-11S, MW-11D, MW-13S, MW-13D, MW-15D). Where the maximum concentration of compound was below detection limit, no mean value was calculated. The background dose levels are presented in Tables 3-4 through 3-6.

Based on the assumptions used in calculating dose, the largest estimated dose for the organic compounds is from inhalation, followed by ingestion and dermal absorption.

Risk Characterization

The risk characterization associated with the no action alternative is presented in three parts, a comparison of contaminant levels with standards or criteria, a comparison of estimated human dose with a reference dose level or acceptable daily intake level, and a calculation of increased lifetime cancer risk.

Maximum and mean concentrations of contaminants in water, as determined previously, and Applicable or Relevant and Appropriate (ARAR) and site-specific

goals, are presented in Table 3-7. With this exception of beryllium and nickel, all of the maximum concentrations of indicator chemicals are above the site-specific ARAR or goal cited. Mean concentrations of trichloroethene, tetrachloroethene, arsenic, barium and lead, are above the ARAR and goal levels cited while the mean concentration of chlorodane is equal to the ARAR and exceeds the site specific goal site. Chlorodane was detected in only two samples, so that the mean concentration is equal to the analytical contract detection limit. The standards are set to protect health and the environment. Exceeding health based standards indicates that given the level of contaminants detected, adverse health effects may occur.

Reference Dose (RFD) and Acceptable Daily Intake (ADI) levels are based on the assumption that thresholds exist for non carcinogens. The RFD and ADI are considered the level unlikely to cause significant noncarcinogenic adverse health effects in humans exposed for a lifetime. An RFD or ADI was available for most of the indicator chemicals and are listed in Table 4-5. An RFD was derived for arsenic from a NOAEL of 17 ug/l in drinking water for humans in 37 villages in Taiwan. Assuming an ingestion rate of 2 liters of water per day, an average body weight of 70 kilograms and a safety factor of 10 to protected sensitive subpopulations who might not be represented in the Taiwan study, the derived RFD for arsenic is 0.05 g/kg/day.

The hazard ratio is the ratio of calculated dose to reference dose. Where the ratio exceeds one, adverse health effects may occur from a lifetime exposure to the cited contaminant level. The overall Hazard Index (HI), is a sum of the chemical-specific ratio. While the HI is most appropriate to use when a variety of compounds act on the same organ, it is a useful tool in gauging the potential effects of environmental exposures to mixtures of carcinogens. The assumption of additivity is likely to overestimate hazard where chemicals act on a different organs, and underestimate hazard where synergistic effects are expected.

A comparison of calculated total dose levels with RFD and ADIs in Table 3-8, shows that the estimated maximum exceeds the cited threshold level in seven of the ten cases of total adult dose investigated, and nine of the ten child dose levels calculated. This indicates that exposure to contaminants at the maximum concentration detected, over a lifetime, may lead to noncarcinogenic adverse health effects.

A comparison of mean doses shows that trichloroethene, chlorodane, arsenic, and lead average doses exceed RFDs and ADIs for adults. Child mean doses exceed RFDs and ADI for trichloroethene, chlorodane, arsenic, beryllium and lead. RFDs and ADIs are developed assuming lifetime exposure, and so may not be relevant for comparing with dose levels calculated for exposure to children. However, this information has been provided to present a complete evaluation of the contamination as well as provide information on the range of likely dose levels.

Background dose levels and hazard ratios were calculated and are presented in Table 3-9. The adult dose of arsenic exceeds the reference dose, and the child background dose of arsenic lead and silver exceed the cited dose.

The hazard index from an adult exposure to plume contamination is 12.98 and 174.33 for mean and maximum exposures respectively. The background hazard index is 0.60 for mean dose and 4.03 for maximum doses of indicator chemicals.

Increased lifetime cancer risks were calculated by multiplying calculated adult dose by the carcinogenic potency factor. Where available, route specific dose estimates and carcinogenic potency factors were used to calculate route specific risk. Route specific risk levels were added to determine total risk. Chromium is considered a carcinogen via inhalation but is not classified via oral exposure. Drinking water criteria (adjusted AWQC, MCL, and drinking water health advisories) are not set based on carcinogenic risk. While it is not clear

whether it should be included in the estimation of increased lifetime cancer risk from ingestion of drinking water, it is included here. Where no oral carcinogenic potency factor is available, cancer risk is calculated by multiplying total estimated dose by the carcinogenic potency factor for inhalation.

Lead salts are classified as B2 carcinogens, however, most lead and lead compounds are considered possible human carcinogens (Group C) with only limited evidence of carcinogenicity in animals. Lead and silver (Group D) are not included in calculated increased lifetime cancer risk from exposure to water at the Montgomery Township Housing Development.

The increased individual lifetime cancer risk associated with a given exposure is expressed as a small fraction (e.g., $1x10^{-6}$ or one in a million). It represents the incremental increase in an individual's lifetime risk or chance of developing cancer which is attributable to that exposure. Another way to view a one in a million risk is given an exposure to one million people, one additional cancer is likely to occur. The level of increased cancer risk considered negligible is still widely debated, but among scientific and regulatory communities it is currently accepted to be in the range of $1x10^{-7}$ to $1x10^{-5}$.

The results of the risk calculations from exposure at the Montgomery Township Housing Development are presented in Table 3-10. All of the increased lifetime cancer risks are larger than one in one hundred thousand (1×10^{-5}). Increased lifetime cancer risk for exposures to maximum and mean concentrations of organic compounds detected in water range from 1.80×10^{-5} to 6.18×10^{-4} for mean exposure to tetrachloroethene and maximum exposure to trichloroethene, respectively.

The increased lifetime cancer risk associated with exposure to metals are higher than those for organic compounds. The largest increased lifetime cancer risk is associated with exposure to the maximum and mean concentration of chromium 4.76×10^{-1} and 3.39×10^{-2} respectively. At first glance, this does not

appear to agree well with the previous observation that the mean concentration of chromium in water samples is below the cited ARARS. The water criterion and ADI are not intended to protect against potential carcinogenic effects of chromium (+6) compounds. It was felt that Cr(+6) would be reduced to Cr(+3) in the gastrointestinal tract, and thus, exposure to the Group A carcinogen Cr(+6) would be minimized. Conclusive data on this assumption are not available (USEPA, 1984). Other calculated risks for metals range from 7.78×10^{-4} to 7.97×10^{-2} for an exposure to the mean concentrations of beryllium and maximum concentrations of arsenic, respectively.

Carcinogenic risks are assumed to be additive and are summed to determine total upper bound increased lifetime cancer risks from exposure to water at Montgomery Township Housing Development. The total upper bound risk level is estimated as 4.23×10^{-2} to 5.7×10^{-1}.

Increased lifetime cancer risks from exposure to background levels of indicator chemicals at the site presented in Table 3-11, are estimated as 1.22×10^{-2} to 2.0×10^{-2}.

Uncertainty Analysis. The uncertainty associated with the health risk calculated is the result of the uncertainty associated with the data as well as the assumptions used in developing the exposure scenarios. Seven general sources of uncertainty have been identified by NJDEP (NJDEP, 1986). They include:

- o environmental sampling;
- o analytical chemistry;
- o environmental parameter measurement;
- o fate and transport modeling;
- o exposure scenario development;
- o toxicological data; and
- o complex interactions of the above.

The first three sources of uncertainty are common to any sampling and measurement routine. The uncertainties are associated with the representativeness of the sampling, as well as the analytical capabilities of the instrumentation.

There is uncertainty associated with modeling environmental concentrations. For example, in the simple one compartment model for calculating the projected concentrations of volatile compounds in air, a proportionality constant of 0.3 L/m^3 was multiplied by the concentration of compound in the water. Work by Andelman indicates that the constant used assumes typical air exchange, water use, and other pertinent home parameters, however, the expected range over which the true value may vary is 0.01 to 0.5 L/m^3 (Andelman, 1986). To calculate a more precise value, transfer coefficients for a specific chemical and a variety of indoor air model parameters would have to be known (Andelman, 1986).

In developing the exposure scenario, simplifying assumptions are used to calculate dose. The assumptions are outlined in the text. The uncertainty associated with the assumptions used may result in overestimating or underestimating dose. In general, conservative assumptions are used to avoid underestimation. For example, when calculating dose, maximum and mean environmental concentrations are used to provide a range of possible exposures. The determination of the mean included the assumption that for samples where the indicator chemical was not detected, the contract detection limit would be used in the calculation. This method was used to avoid underestimating dose.

Uncertainties associated with toxicological data often include uncertainties associated with the animal experimentation, uncertainties associated with extrapolating high experimental doses to low doses generally of concern given environmental conditions, and the uncertainties associated with extrapolating human health effects from animal data.

Given the variety of uncertainties associated with each step of the risk assessment process, no numerical estimate of uncertainty has been made. The evaluation should therefore not be considered a determination of absolute risks, rather a method to identify the areas of greatest concern for developing remediation alternatives.

TABLE 3-1. Total Adult Human Dose from Exposure to Organic Compounds in Water.

Substance	Concentration in Water (ug/l) Maximum	Mean	Inhaled Dose (1) (ug/kg/day) Maximum	Mean	Ingested Dose (2) (ug/kg/day) Maximum	Mean	Dermal Dose (3) (ug/kg/day) Maximum	Mean	Total Dose (4) (ug/kg/day) Maximum	Mean
Trichloroethene	650	62.6	55.71	5.37	18.57	1.79	14.33	1.38	88.61	8.53
Tetrachloroethene	43	6.6	3.69	0.57	1.23	0.19	0.95	0.15	5.86	0.90
Chlordane	1.3	0.5	0.11	0.04	0.04	0.01	0.03	0.01	0.18	0.07

1. Inhaled dose = (concentration in air) x (20 m3 inhaled/day) / 70 kg body weight
   Concentration in air(ug/m3) = 0.3(l/m3) x concentration in water(ug/l)
2. Ingested dose = (concentration in water) x (2 liters/day) / 70 kg body weight
3. Dermal dose = (concentration in water)(SA)(F)(perm. constant)(t)(3days/7days)/70 kg
   where: F = fraction of the body exposed or 0.80
   t = length of exposure or 0.25 hours/day
   SA = total body surface area or 18000 cm2
   Perm. constant = 0.001 l/cm2 hr

TABLE 3-2. Total Child Dose from Exposure to Organic Compounds in Water.

Substance	Concentration in Water (ug/l) Maximum	Mean	Inhaled Dose (1) (ug/kg/day) Maximum	Mean	Ingested Dose (2) (ug/kg/day) Maximum	Mean	Dermal Dose (3) (ug/kg/day) Maximum	Mean	Total Dose (4) (ug/kg/day) Maximum	Mean
Trichloroethene	650	62.6	156.00	15.02	65.00	6.26	48.75	4.70	269.75	25.98
Tetrachloroethene	43	6.6	10.32	1.58	4.30	0.66	3.23	0.50	17.85	2.74
Chlordane	1.3	0.5	0.31	0.12	0.13	0.05	0.10	0.04	0.54	0.21

1. Inhaled dose = (concentration in air) x (8 m3 inhaled/day) / 10 kg body weight
   Concentration in air(ug/m3) = 0.3(l/m3) x concentration in water(ug/l)
2. Ingested dose = (concentration in water) x (1 liters/day) / 10 kg body weight
3. Dermal dose = (concentration in water)(SA)(F)(perm. constant)(t)(7days/7days)/10 kg
   where: F = fraction of the body exposed or 0.75
   t = length of exposure or 0.25 hours/day
   SA = total body surface area or 4000 cm2
   Perm. constant = 0.001 l/cm2 hr

Table 3-3. Total Human Dose from Exposure to Metals in Water

Substance	Concentration in water (ug/l)		Ingested Dose (ug/kg/day) Adult (1)		Child (2)	
	Maximum	Mean	Maximum	Mean	Maximum	Mean
Arsenic	186	13.3	5.31	0.38	18.6	1.33
Barium	2300	173.7	65.71	4.96	230	17.37
Beryllium	17	5.6	0.49	0.16	1.7	0.56
Chromium	406	28.9	11.60	0.83	40.6	2.89
Lead	2170	91.9	62.00	2.63	217	9.19
Nickel	340	52.7	9.71	1.51	34	5.27
Silver	180	15.2	5.14	0.43	18	1.52

1. Ingested dose = (concentration in water) x (2 liters/day) / 70 kg body weight
2. Ingested dose = (concentration in water) x (1 liters/day) / 10 kg body weight

TABLE 3-4. Total Adult Human Dose from Exposure to Background Levels of Organic Compounds in Water.

Substance	Concentration in Water (ug/l) Maximum	Mean	Inhaled Dose (1) (ug/kg/day) Maximum	Mean	Ingested Dose (2) (ug/kg/day) Maximum	Mean	Dermal Dose (3) (ug/kg/day) Maximum	Mean	Total Dose (4) (ug/kg/day) Maximum	Mean
Trichloroethene	ND	ND	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tetrachloroethene	1.4	BDL	0.12	0.00	0.04	0.00	0.03	0.00	0.19	0.00
Chlordane	ND	ND	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

****

1. Inhaled dose = (concentration in air) x (20 m3 inhaled/day) / 70 kg body weight
   Concentration in air(ug/m3) = 0.3(l/m3) x concentration in water(ug/l)
2. Ingested dose = (concentration in water) x (2 liters/day) / 70 kg body weight
3. Dermal dose = (concentration in water)(SA)(F)(perm. constant)(t)(3days/7days)/70 kg
   where: F = fraction of the body exposed or 0.80
   t = length of exposure or 0.25 hours/day
   SA = total body surface area or 18000 cm2
   Perm. constant = 0.001 l/cm2 hr

ND Not Detected

BDL The maximum concentration detected was below contract detection limits, and no mean concentration was calculated.

TABLE 3-5. Total Child Dose from Exposure to Background Levels of Organic Compounds in Water.

Substance	Concentration in Water (ug/l) Maximum	Mean	Inhaled Dose (1) (ug/kg/day) Maximum	Mean	Ingested Dose (2) (ug/kg/day) Maximum	Mean	Dermal Dose (3) (ug/kg/day) Maximum	Mean	Total Dose (4) (ug/kg/day) Maximum	Mean
Trichloroethene	ND	ND	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tetrachloroethene	1.4	BDL	0.34	0.00	0.14	0.00	0.11	0.00	0.58	0.00
Chlordane	ND	ND	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

****

1. Inhaled dose = (concentration in air) x (8 m3 inhaled/day) / 10 kg body weight
   Concentration in air(ug/m3) = 0.3(l/m3) x concentration in water(ug/l)
2. Ingested dose = (concentration in water) x (1 liters/day) / 10 kg body weight
3. Dermal dose = (concentration in water)(SA)(F)(perm. constant)(t)(7days/7days)/10 kg
   where: F = fraction of the body exposed or 0.75
   t = length of exposure or 0.25 hours/day
   SA = total body surface area or 4000 cm2
   Perm. constant = 0.001 l/cm2 hr

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Table 3-6. Total Human Dose from Exposure to Background Levels of Metals in Water

Substance	Concentration in water (ug/l)		Ingested Dose (ug/kg/day) Adult (1)		Child (2)	
	Maximum	Mean	Maximum	Mean	Maximum	Mean
Arsenic	4.1	BDL	0.12	0.00	0.41	0
Barium	232	97.3	6.63	2.78	23.2	9.73
Beryllium	3.8	BDL	0.11	0.00	0.38	0
Chromium	14	9.4	0.40	0.27	1.4	0.94
Lead	39	12.9	1.11	0.37	3.9	1.29
Nickel	40	34.2	1.14	0.98	4	3.42
Silver	36	13.6	1.03	0.39	3.6	1.36

****

1. Ingested dose = (concentration in water) x (2 liters/day) / 70 kg body weight
2. Ingested dose = (concentration in water) x (1 liters/day) / 10 kg body weight

TABLE 3-7. COMPARISON WITH STANDARDS AND CRITERIA

Substance	Concentration ug/l Maximum	Mean	Site-Specific ARAR (a) ug/l	Site-Specific Goal (a) ug/l
Trichloroethene	650	62.6	1	3.2
Tetrachloroethene	43	6.6	1	0.69
Chlordane	1.3	0.5	0.5	0
Arsenic	186	13.3		0.002
Barium	2300	173.7	50	1500
Beryllium	17	56	1000	NA
Chromium	406	28.9	50	120
Lead	2170	91.9	50	10
Nickel	340	52.7	NA	350
Silver	180	15.2	50	NA

a. Site-Specific ARAR or goal to be considered as listed in Table 2.1.

Table 3-8. Comparison of Total Dose with Reference Dose

Substance	Total Dose (ug/kg/day) Adult Maximum	Adult Mean	Child Maximum	Child Mean	RfD or ADI(a) (ug/kg/day)	Hazard Ratio(g) Adult Maximum	Adult Mean	Child Maximum	Child Mean
Trichloroethene	88.61	8.53	269.75	25.98	7 (d)	12.66	1.22	38.54	3.71
Tetrachloroethene	5.86	0.90	17.85	2.74	20 (c)	0.29	0.04	0.89	0.14
Chlordane	0.18	0.07	0.54	0.21	0.05 (e)	3.54	1.36	10.79	4.15
Arsenic	5.31	0.38	18.60	1.33	0.05 (f)	106.29	7.60	372.00	26.60
Barium	65.71	4.96	230.00	17.37	51 (e)	1.29	0.10	4.51	0.34
Beryllium	0.49	0.16	1.70	0.56	0.5 (e)	0.97	0.32	3.40	1.12
Chromium	11.60	0.83	40.60	2.89	5 (b)(e) 1000 (b)(c)	2.32	0.17	8.12	0.58
Lead	62.00	2.63	217.00	9.19	1.4 (e)	44.29	1.88	155.00	6.56
Nickel	9.71	1.51	34.00	5.27	10 (e)	0.97	0.15	3.40	0.53
Silver	5.14	0.43	18.00	1.52	3 (c)	1.71	0.14	6.00	0.51
Hazard Index(h)						174.33	12.98	602.65	44.23

a. Reference dose or Acceptable daily intake
b. Cr(+6) 5.0
   Cr(+3) 1000
c. USEPA, IRIS, 1986
d. ICAIR, 1985
e. ICF, 1986
f. NOAEL from a human exposure to drinking water.
   NOAEL = 17 ug/l
   derived RfD = 0.05 ug/kg/day
g. Hazard Ratio=Calculated Dose/Reference Dose
h. Hazard Index=Sum of the hazard ratios for each chemical

Table 3-9. Comparison of Total Background Dose with Reference Dose

Substance	Total Dose (ug/kg/day) Adult Maximum	Adult Mean	Child Maximum	Child Mean	RfD or ADI(a) (ug/kg/day)	Hazard Ratio(g) Adult Maximum	Adult Mean	Child Maximum	Child Mean
Trichloroethene	0.00	0.00	0.00	0.00	7 (d)	0.00	0.00	0.00	0.00
Tetrachloroethene	0.19	0.00	0.58	0.00	20 (c)	0.01	0.00	0.03	0.00
Chlordane	0.00	0.00	0.00	0.00	0.05 (e)	0.00	0.00	0.00	0.00
Arsenic	0.12	0.00	0.41	0.00	0.05 (f)	2.34	0.00	8.20	0.00
Barium	6.63	2.78	23.20	9.73	51 (e)	0.13	0.05	0.45	0.19
Beryllium	0.11	0.00	0.38	0.00	0.5 (e)	0.22	0.00	0.76	0.00
Chromium	0.40	0.27	1.40	0.94	5 (b)(e) 1000 (b)(c)	0.08	0.05	0.28	0.19
Lead	1.11	0.37	3.90	1.29	1.4 (e)	0.80	0.26	2.79	0.92
Nickel	1.14	0.98	4.00	3.42	10 (e)	0.11	0.10	0.40	0.34
Silver	1.03	0.39	3.60	1.36	3 (c)	0.34	0.13	1.20	0.45
Hazard Index(h)						4.03	0.60	14.11	2.10

a. Reference dose or Acceptable daily intake
b. Cr(+6) 5.0
   Cr(+3) 1000
c. USEPA, IRIS, 1986
d. ICAIR, 1985
e. ICF, 1986
f. NOAEL from a human exposure to drinking water.
   NOAEL = 17 ug/l
   derived RfD = 0.05 ug/kg/day
g. Hazard Ratio=Calculated Dose/Reference Dose
h. Hazard Index=Sum of the hazard ratios for each chemical

Table 3-10. Increased Lifetime Cancer Risks

Substance	Carcinogenic Potency Factor (mg/kg/day)-1 (c) oral	inhalation	All Exposures Increased Lifetime Cancer Risk maximum	mean	Inhaled Increased Cancer Risk maximum	mean	Ingested Increased Cancer Risk maximum	mean	Dermal Increased Cancer Risk maximum	mean
Trichloroethene	0.011	0.0046	6.18E-04	5.95E-05	2.56E-04	2.47E-05	2.04E-04	1.97E-05	1.58E-04	1.52E-05
Tetrachloroethene	0.051	0.0017	1.17E-04	1.80E-05	6.27E-06	9.62E-07	6.27E-05	9.62E-06	4.83E-05	7.42E-06
Chlordane	1.61	(b)	2.85E-04	1.10E-04	1.79E-04	6.90E-05	5.98E-05	2.30E-05	4.61E-05	1.77E-05
Arsenic	15	50	7.97E-02	5.70E-03	-	-	-	-	-	-
Beryllium	(a)	4.86	2.36E-03	7.78E-04	-	-	-	-	-	-
Chromium	(a)	41	4.76E-01	3.39E-02	-	-	-	-	-	-
Nickel	(a)	1.19	1.16E-02	1.79E-03	-	-	-	-	-	-
TOTAL			5.70E-01	4.23E-02						

a. Used CPF for the inhalation route, for all exposure routes.
b. Used CPF for the oral route for all exposure routes.
c. ICF,1986
NA Not Applicable
Calculations:
Adult doses were used to calculate risk, one of the following equations was used depending on available data.
1. CR = (IG)(CPF-O)+(IH)(CPF-I)+(DD)(larger CPF)
2. CR = (TD)(CPF)
where: IG - ingested dose, IH - inhaled dose, DD - dermal dose
TD - total dose, CPF - carcinogenic potency factor

Table 3-11. Increased Lifetime Cancer Risks from Exposure to Background Levels of Indicator Chemicals

Substance	Carcinogenic Potency Factor (mg/kg/day)-1 oral	inhalation	All Exposures Increased Lifetime Cancer Risk maximum	mean	Inhaled Increased Cancer Risk maximum	mean	Ingested Increased Cancer Risk maximum	mean	Dermal Increased Cancer Risk maximum	mean
Trichloroethene	0.011	0.0046	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tetrachloroethene	0.051	0.0017	3.82E-06	0.00E+00	2.04E-07	0.00E+00	2.04E-06	0.00E+00	1.57E-06	0.00E+00
Chlordane	1.61	(b)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Arsenic	15	50	1.76E-03	0.00E+00	-	-	-	-	-	-
Beryllium	(a)	4.86	5.28E-04	0.00E+00	-	-	-	-	-	-
Chromium	(a)	41	1.64E-02	1.10E-02	-	-	-	-	-	-
Nickel	(a)	1.19	1.36E-03	1.16E-03	-	-	-	-	-	-
TOTAL			2.00E-02	1.22E-02						

a. Used CPF for the inhalation route, for all exposure routes.
b. Used CPF for the oral route for all exposure routes.
NA Not Applicable
Calculations:
Adult doses were used to calculate risk, one of the following equations was used depending on available data.
1. CR = (IG)(CPF-O)+(IN)(CPF-I)+(DD)(larger CPF)
2. CR = (TD)(CPF)
where: IG - ingested dose, IN - inhaled dose, DD - dermal dose
TD - total dose, CPF - carcinogenic potency factor

SECTION 4
ALTERNATIVE IDENTIFICATION AND SCREENING

GENERAL

Water supply alternatives for the Montgomery Township Housing Development wells have been identified and reviewed. The alternative water supplies address the 39 private wells identified in Chapter 1.

An average daily demand of 280 gallons per day (gpd) per household is used in developing the alternatives, except in Alternative 1--Bottled Water, which only addresses potable water.

ALTERNATIVE DESCRIPTIONS

Available information on existing sources of supply, treatment technologies, and water supply technologies has been reviewed to develop remedial alternatives. Based on this review, four (4) potentially viable water supply alternatives have been identified. These alternatives include temporary drinking water, supplied as bottled water or supplied by Elizabethtown Water Company through taps on their existing water mains, permanent water supply from Elizabethtown Water Company's system, groundwater treatment at each individual well, and installation of a community well with a centralized treatment system. A no-action alternative, for which residents will continue using the contaminated well water, will also be considered.

Alternative 1 - Temporary Drinking Water

The use of temporary drinking water for potable water use is a potential alternative to be implemented during the interim time period until a permanent alternative water supply can be provided for the Montgomery Township

residents. Therefore a period of two years has been estimated as the maximum amount of time that residents will use the temporary drinking water source until the permanent source is available.

Temporary drinking water can be supplied for the residences with contaminated wells from the Elizabethtown Water Company, through taps on their existing water mains, or from bottled water delivered to each of the 39 affected homes.

The average daily demand for each of the 39 residences is established for drinking and cooking purposes only for Alternative 1. Temporary supply for all domestic water needs is impractical since residents would have to collect and transport the water to their homes from a tap on Elizabethtown's water mains and a majority of bottled water vendors supply 5 or 6 gallons storage containers mounted on a free-standing dispenser (i.e. bulk storage and dispensing facilities for purchased water would be required for each residence). Therefore, all other domestic water needs (e.g. sanitary, bathing, washing, etc.) would continue to be met through the existing contaminated well supplies for this alternative. As a result, airborne exposure to contaminants would still continue with this alternative.

Temporary Water Provided by Elizabethtown Water Company. The Elizabethtown Water Company would install centrally located metered water service in the Montgomery Township Housing Development to provide potable water. The residents would be furnished with one or 2.5 gallon containers for collecting and storing their domestic water needs for drinking and cooking.

Based on an assumed domestic water demand of one (1) gpd per person, the estimated demands for drinking and cooking needs for the homes would be met using the temporary supply. Based on use of one-gallon containers, it is assumed that each home would store six (6) one-gallon containers and it is estimated that every two days each homeowner would be required to pick up water for their needs.

The temporary water service provided by the water company would be insulated for cold weather protection during winter operations. In addition, a security fence would be required at the site to prevent vandalism.

Bottled Water. Based on an assumed domestic water demand of one (1) gpd per person, the estimated demand for drinking and cooking needs for the homes would be met using bottled water with free-standing cold water cooler/dispenser. Water would be delivered in 11 five-gallon containers to each home every three (3) weeks. It is estimated that each water delivery for 39 residences would consist of 2,145 gallons of water, or 429 five-gallon bottles.

Alternative 2 - Elizabethtown Water Company

Elizabethtown Water Company is currently supplying water to 38 of the 77 residents in the Montgomery Township Housing Development.

The existing Elizabethtown Water Company's water distribution system for the Montgomery Township Housing Development is shown in Figure 4-1. To address the problem of the contaminated residential wells by replacing them with a potable water supply would require the extension of the Elizabethtown supply service system.

The facilities to extend the Elizabethtown water system, which make up Alternative 2 are also shown in Figure 4-1. The facilities required to extend the existing distribution system include: approximately 4000 feet of eight (8) inch ductile iron pipe; five (5) isolation valves and thirty-nine (39) service connections. The new water main has been sized to handle any additional demands in the service area. The location of water mains and appurtenances and water service would be finalized during the design phase.

The implementation of this alternative would result in the abandoning of the individual residential wells. The abandoned wells will be sealed in accordance with NJSA Standard Specifications for Sealing of Abandoned Wells.

Alternative 3 - Individual Well Water Treatment

Alternative 3A - Air Stripping with Granular Activated Carbon Adsorption. Based on the raw water quality (Appendix B) and the State of New Jersey Interim Groundwater Cleanup Criteria countercurrent air stripping in conjunction with granular activated carbon and adsorption has been identified as acceptable for treating the contaminated groundwater of the 39 residential wells in the Montgomery Township Housing Development.

Table 4-1 lists the Henry's Law Constants for the organic chemicals found in the residential wells at concentrations exceeding the allowable maximum contaminant level (MCL), as presented in Table 2-1, as well as carbon requirement values based on milligram (mg) of contaminant adsorbed per gram of carbon for the organics that exceed the MCLs. As a general rule, chemical compounds having a Henry's Law Constant of 150 or greater are readily air strippable. Compounds having a Henry's Law Constant of at least 50 are potentially good candidates for air stripping. Therefore, nearly all of the organic contaminants identified at concentrations greater than the MCLs can be readily removed from the well water to an acceptable level by a properly operated stripping column. Those contaminants that may not be reliably removed by air stripping, including 1,2-dichloroethane, and 1,2-dichlorobenzene, are amenable to removal by adsorption onto granular activated carbon.

With this system, well water treatment would be provided through the installation of individual water treatment systems in each affected residence or on each residential property. Each individual treatment unit would provide enough capacity to meet the demands of an individual household. The individual treatment facility components are shown in Figure 4-2.

For treatment by air stripping volatile organic contaminants would be removed by countercurrent packed tower aeration. Contaminated water would be

brought into intimate contact with air so that the volatile compounds undergo a phase change from the liquid phase to the vapor phase. The contaminants would then be removed with the exhaust air.

Because of the low flow rates required, the discontinuous and fluctuating water usage rate, and the desire to have a relatively small tower, a batch type packed tower aeration system would be most practical. The aeration system would consist of a small packed tower and associated blowers, pumps, and controls. Water would be recycled through the packed tower until the desired treated water quality associated with a specific residence time had been obtained. The residence time would be predetermined based on routine monitoring. The water would then be pumped through in-line dual activated carbon cartridges for removal of those contaminants that are not removed by air stripping and into the treated water storage tank. Upon completion of the batch, a new batch would be treated.

The system would have high/low level controls to start and stop batch production. Well water would be recirculated through the tower three times to provide treatment based on a maximum TCE value of 650 ppb, with a 20 percent safety factor. The system would be installed on each residential property and winterized to maintain operation in cold weather by insulating the unit and providing minimal heating. Installation would also involve associated piping to tie the treatment systems into the residential well and plumbing system.

While there is no reason to suspect groundwater microbiological pollution, there is the potential for biological growth in the detention devices of the treatment systems (i.e. GAC adsorption cartridges, packed towers, storage tanks). Therefore, an ultraviolet disinfection system would be provided for pathogen control. This system offers the advantage of simple installation and maintenance, relatively little operator attention, no dangerous chemicals, and minimum space requirements.

It will be necessary to sample and analyze the raw well water, the water after the first carbon cartridge and the treated water several times during a year in order to monitor the treatment efficiency of the system. For alternative 3A, which includes both air stripping and granular activated carbon adsorption, the system will be sampled during startup, 45 days after startup, then at least three times yearly.

By sampling after the first of the two carbon cartridges (the lead cartridge) breakthrough, the point at which contaminants are no longer being adsorbed by the lead cartridge will be determined, indicating the need for carbon replacement.

Alternative 3B - Granular Activated Carbon Adsorption. This system is essentially the same as Alternative 3A without air stripping. The individual treatment facility components are shown in Figure 4-3.

Since trichloroethene (TCE) is the contaminant identified in the Montgomery Township Housing Development in significant concentrations which is the least amenable to adsorption onto granular activated carbon, the TCE concentration will be the controlling factor in the frequency of carbon replacement and the frequency of monitoring required. Based on a mean concentration of 160 ppb TCE, a minimum of 130 lbs of carbon will be required annually. If the maximum concentration of 650 ppb is used as the basis for carbon replacement, the annual requirement will be 1400 lbs of carbon. Since carbon replacement is being estimated for the 39 wells, no less than 130 lbs of carbon required annually per residence will be used as a starting point for this alternative. If methylene chloride is present in the well water, the carbon usage will increase significantly. The magnitude of the increase will depend on the methylene chloride concentration.

Since carbon adsorption is the sole means of organic contaminant removal for this system, it will be necessary to monitor the system for contaminant breakthrough based on the TCE concentration. With an average TCE

concentration of 160 ppb and a daily water usage of 280 gallons per day contaminant breakthrough from the lead carbon cartridge could potentially occur after 60 days. The higher the TCE concentration in the well water, the sooner breakthrough will occur. To ensure that the carbon is being replaced soon enough so that the water is being treated to the desired quality, the raw water, water after the lead carbon cartridge and the treated water should be monitored every 30 days.

Generally, this system will be more technically reliable than alternative 3A since fewer mechanic components are required. There is, however, greater potential for exceeding the standards for both TCE and methylene chloride, if present, if the system is not closely monitored. It is expected that the granular activated carbon will be replaced up to five times more frequently than for Alternative 3A.

Alternative 4 - New Centralized Community Well with Well Water Treatment

A new well would be located and installed on a purchased parcel of land somewhere in the housing development or surrounding area. A treatment system of sufficient capacity to meet the combined water demand of the 39 residential households would be constructed to treat the well water to a level that meets applicable standards with the possible exception of some heavy metals. The treatment facility components, shown in Figure 4-4, are described below.

The community well treatment system would be similar to the individual well treatment system Alternative 3A, described previously except that a single pass through the system would be sufficient for the required removal, the carbon adsorption system would consist of a single disposable cartridge, the system would operate on a continuous rather than a batch mode, and chlorine rather than ultraviolet radiation would be used for disinfection.

Based on the maximum contaminant levels identified in the available data, a 30 foot packed tower with 25 feet of packing would be required to effectively remove all volatile organics from the groundwater. This tower height includes a twenty-five percent safety factor to ensure that complete removal is achieved.

Raw and treated water storage would be required to provide a buffer for fluctuating demand throughout a day. The community well system would require a distribution network system to collect and transport the water to the individual residences. Distribution pumps with recycle and distribution piping would be used for this purpose. Disinfection would be provided by chlorination to ensure residual disinfection throughout the distribution system. A standby generator would be included in case of power failure.

Like Alternative 2, the implementation of this alternative would result in the abandoning of the individual residential wells. The abandoned wells will be sealed in accordance with NJSA Standard Specifications for Sealing of Abandoned Wells.

ALTERNATIVE SCREENING

An initial screening of alternatives is conducted to narrow the list of potential remedial actions for further detailed analysis, as appropriate. SARA identifies three broad criteria for use in justifying the elimination of an alternative from further evaluation. These criteria include effectiveness, implementability and cost factors. First, those alternatives that do not effectively provide protection (i.e., those with significant adverse effects, anc limited environmental benefits) will not be considered further. Second, alternatives must be feasible for the location and conditions of the release, applicable to the problem, and represent reliable means of addressing the problem. Third, an alternative that far exceeds the costs of other alternatives considered and that does not provide substantially greater protection or technical reliability may be excluded from further consideration. The screening of

Table 7

alternatives is a qualitative process based upon specific project information and best professional judgment.

The alternatives which have been screened based on one or more of the three criteria presented are discussed below.

Alternative 1

Temporary water provided by taps on the Elizabethtown Water Company Water mains has been screened out in preference to supplying residences with bottled water due to the greater ease of implementing the bottled water alternative. In addition, use of bottled water can begin immediately, whereas some engineering and construction time will be required before taps would be available on the water mains.

Alternative 3A - Individual Well Treatment - Air Stripping with Granular Activated Carbon Adsorption

Although the installation of individual packed tower aeration and carbon adsorption treatment systems for each residential well would effectively reduce levels of contamination to meet state and federal requirements for organics, this alternative has been screened from further consideration due to the high cost of its implementation, without providing the benefit of a greater degree of treatment than Alternatives 2 and 4. The cost of installing individual treatment systems for each of the 39 wells far exceeds the costs of either extending the Elizabethtown Water Company system or of installing a centralized community well with well water treatment. The preliminary cost estimate prepared for this alternative is presented in Appendix I of this report.

Alternative 3B - Individual Well Treatment - Granular Activated Carbon Adsorption

This alternative has been screened from further consideration due to the excessively high operation and maintenance costs, specifically the cost of carbon replacement, that will be required to assure the effective operation of this alternative. This alternative will potentially provide less effective treatment than Alternatives 3A or 4 since methylene chloride, a possible groundwater contaminant, is not effectively removed by carbon adsorption (Becker, 1978; Metcalf & Eddy, 1987). If methylene chloride were the only contaminant present in the raw well water at a concentration of 5 ppb, the carbon usage will be 1 to 5 lb of carbon per 1000 gallons of well water treated (Calgon, 1987), or up to 500 lbs of carbon per year per residence. Therefore, the possible presence of both methylene chloride and TCE in the well water make the use of granular activated carbon as the sole source of treatment potentially ineffective as well as expensive.

TABLE 4-1. TREATABILITY INDICATORS FOR CONTAMINANTS IN MONTGOMERY TOWNSHIP HOUSING DEVELOPMENT RESIDENTIAL WELLS

Contaminant	Henry's Law Constant @ 10°C[1]	Carbon Requirement Mg Contaminant Adsorbed/gm Carbon [2]
Trichloroethene	336	0.39
1,1,1-Trichloroethane	223	2.5
1,1-Dichloroethane	140	1.8
1,2-Dichloroethane	30.4	3.6
1,1-Dichloroethene	709	4.9
1,2-Dichloroethene	91.7[4]	3.0
Tetrachloroethene	564	50
Methylene Chloride	140[3]	1.3[5]
Ethylbenzene	350[3]	53
Carbon Tetrachloride	720	11
Toluene	154	26
Chloroform	97	2.6
1,2-Dichlorobenzene	37.1	129

(1) M.C. Kavanaugh, R. Trussel, 1980.
(2) EPA, carbon adsorption isotherms for toxic organics, EPA-600/8-80-023, April 1980, unless otherwise noted.
(3) Nyer, Groundwater Treatment Technology, (20°C).
(4) Metcalf & Eddy Data Base.
(5) Based on available data, this compound is not readily adsorbed onto activated carbon (Becker, 1978; Metcalf & Eddy, 1987; Calgon, 1987).

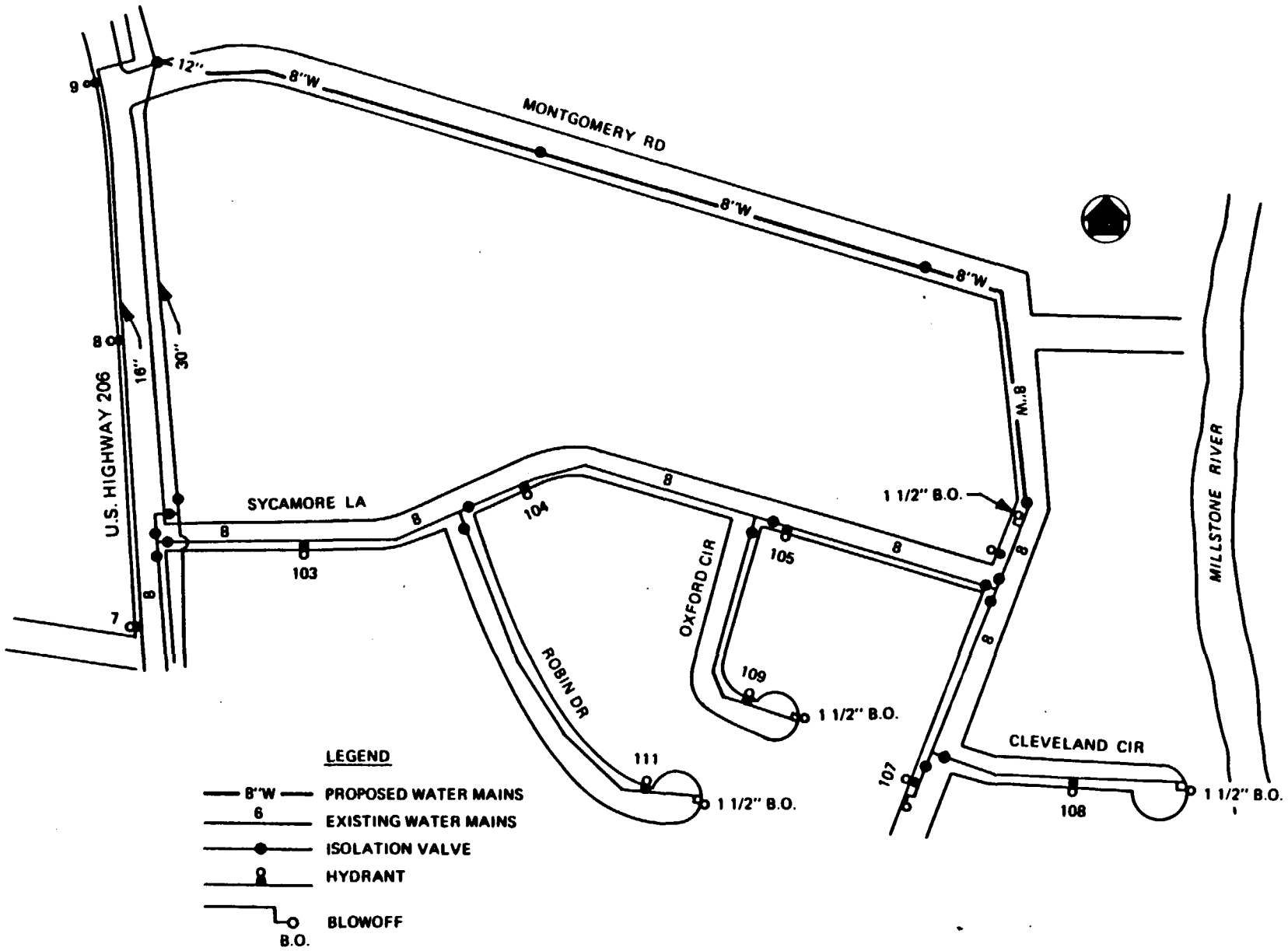

FIGURE 4-1. ELIZABETHTOWN WATER COMPANY WATER DISTRIBUTION SYSTEM

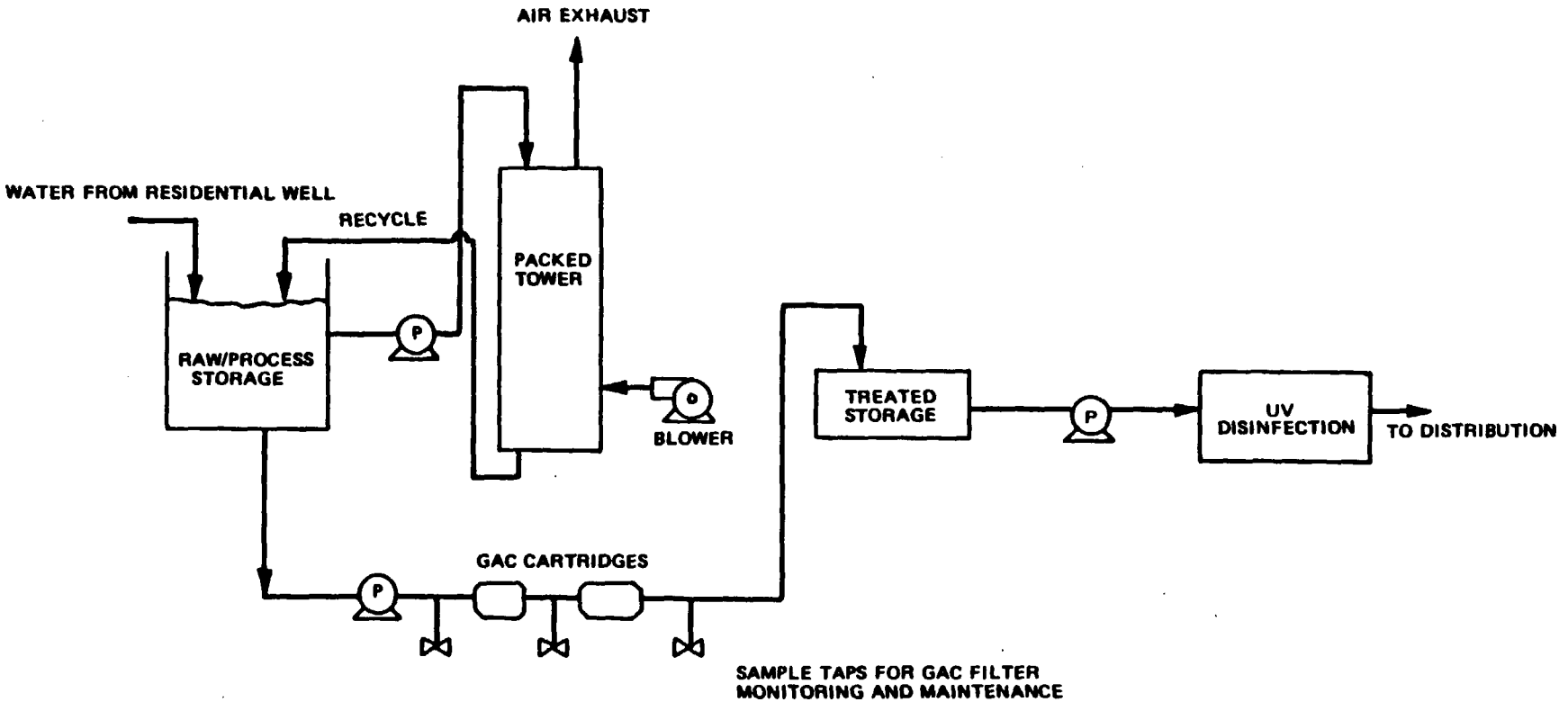

FIGURE 4-2. INDIVIDUAL WELL TREATMENT – AIR STRIPPING WITH GRANULAR ACTIVATED CARBON ADSORPTION

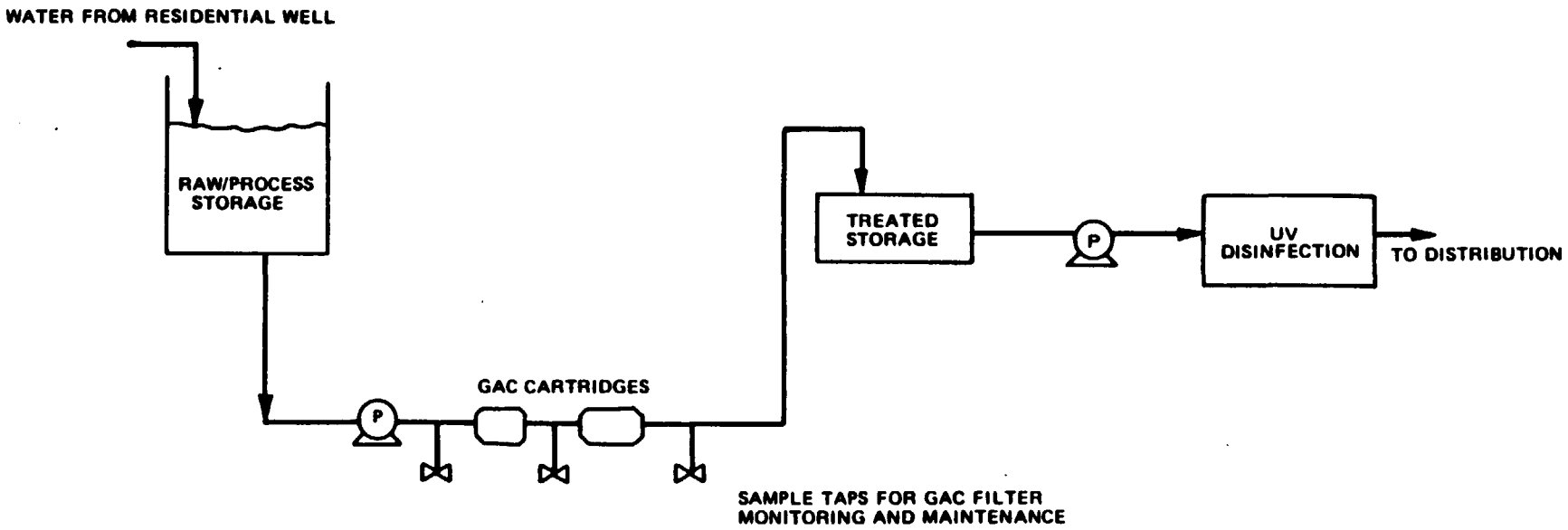

FIGURE 4-3. INDIVIDUAL WELL TREATMENT – GRANULAR ACTIVATED CARBON ADSORPTION

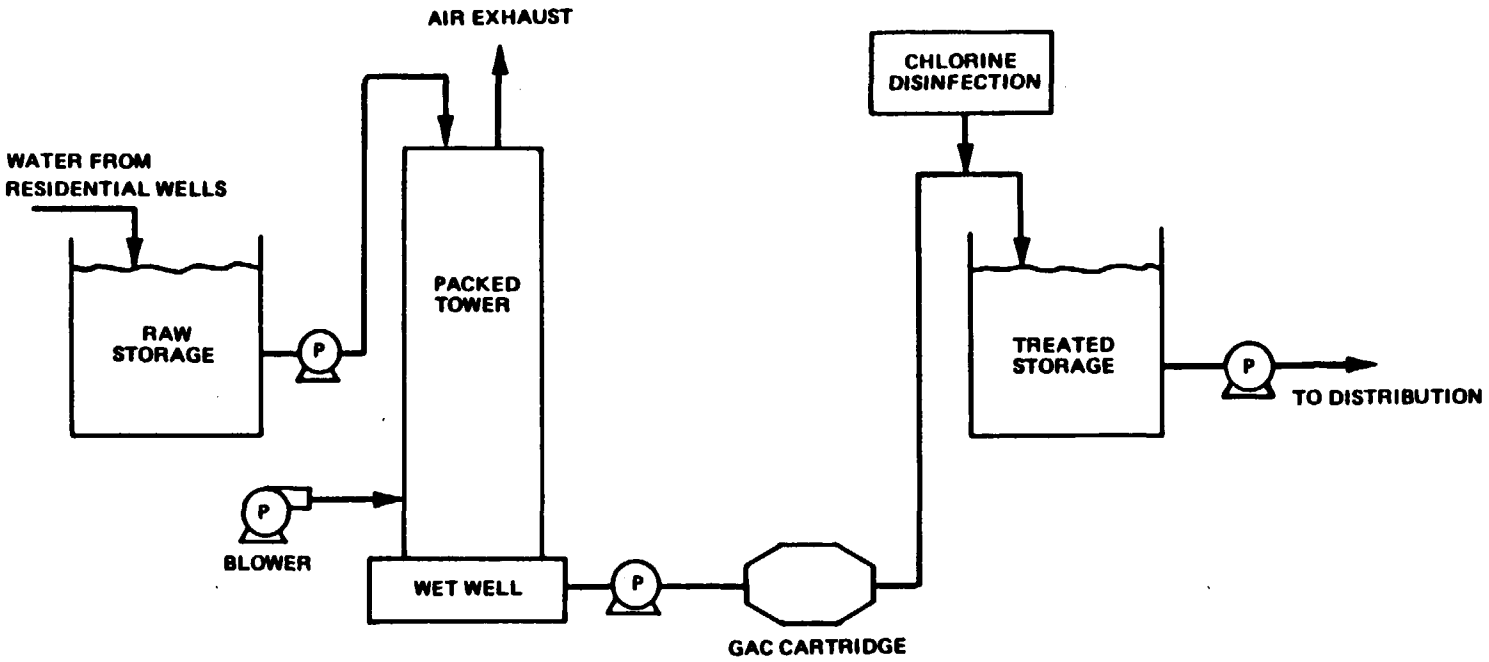

FIGURE 4-4. NEW COMMUNITY WELL WITH WELL WATER TREATMENT SYSTEM

SECTION 5
EVALUATION OF REMEDIAL ALTERNATIVES

GENERAL

The water supply alternatives which have not been eliminated during the screening of alternatives in Section 4 are first evaluated and then summarized for final selection by the NJDEP.

EVALUATION CRITERIA

The criteria used to evaluate the viability of each water supply alternative are consistent with Federal guidelines presented Section 121 of SARA. The criteria used in this evaluation include:

- The effectiveness of the alternatives taking into account whether or not an alternative adequately protects human health and environment and attains Federal and State ARARs, whether or not it significantly and permanently reduces toxicity, and whether or not it is technically reliable.

- The implementability of the alternatives, including the technical feasibility and availability of the technologies each alternative would employ, the technical and institutional ability to monitor, maintain and replace technologies over time; and the administrative feasibility of implementing the alternative.

- Costs of construction and the long-term costs of operating and maintaining the alternatives based on a present worth analysis.

Both the short- and long-term effects of the above factors are assessed, and the remedial alternatives are then compared for their relative strengths and weaknesses.

Water supply alternatives are being considered for the Montgomery Township Housing Development residential wells to prevent potential public health risks related to the use of contaminated well water. In this evaluation, the ability of an alternative to prevent potential public health risks resulting from possible routes of exposure (i.e., ingestion and inhalation) will be discussed. In addition, an analysis of any adverse environmental impacts and methods of mitigation will be reviewed.

The institutional requirements are primarily Federal and State public health and environmental regulations which are pertinent to implementing water supply alternatives. Associated institutional requirements include the planning, appropriate agency review and implementation process requiring preliminary engineering reports, design and permitting, which are alternative specific. Alternatives have been identified and to a limited extent screened based on the institutional requirements identified in Section 2. The institutional evaluation of alternatives considers how well established public health and environmental requirements are met.

An analysis of technical feasibility makes it possible to determine whether implementation of an alternative is technically possible and whether the alternative will function as planned. Consideration is given to whether technologies/equipment are commercially available, whether past use of a technology under similar circumstances has resulted in documented evidence that the technology can reliably meet technical standards (such as a reduction in contaminant levels to predetermined levels), the flexibility to expand capacities of the technology in the event additional contamination is found in the future, and the amount of time that would be required to implement an alternative.

The cost of constructing and operating an alternative has a bearing on its viability since alternatives with similar technical feasibilities and similar abilities to protect public health may have widely different costs. Capital costs considered included the costs of all equipment, materials, labor, engineering as well as administrative costs required to implement an alternative. O&M costs included utility costs, maintenance costs, and monitoring (sampling and analysis) costs on an annual basis. An annualized cost analysis allows a comparison of alternatives with differing capital and O&M estimates and also allows comparison of alternative implementation for different periods of performance. The actual implementation period will depend on the results of the remedial investigation, the types of alternatives identified for source control and control of contaminant migration in addition to administrative considerations made by participating authorities.

Based on the above criteria, each water supply alternative has been evaluated for its technical feasibility, ability to protect public health, and cost as discussed in the following sections. After the alternative assessment, an annualized cost-effectiveness analysis is presented to readily compare alternatives. The cost analysis has been performed for a 5-year, 10-year, and 20-year implementation period using a 10 percent annual interest rate. These time periods have been selected to demonstrate the short-term and long-term advantages of the alternatives evaluated.

ALTERNATIVE EVALUATIONS

Public Health Evaluation

In addition to the no action alternative evaluated in detail, the impact on public health from the other alternatives must be evaluated.

Alternative 1. By supplying the 39 residents who remain on the private residential wells with bottled water, until a permanent remedy can be implemented, health

risks due to ingestion will be eliminated. Risks due to to inhalation and dermal exposure will remain with this alternative. Since it is anticipated that bottled water will be required for a period of up to two-years, risks due to inhalation and dermal contact are only applicable for this period of time. The magnitude of the health risk from inhalation and dermal absorption over a two-year period is expected to be small. The magnitude of the health risk from inhalation and dermal absorption over a two year period is expected to be small. To determine the risk reduction for the temporary drinking water alternative for exposure to organic compounds, the following factors are considered:

- The dose from inhalation and dermal absorption exposure route as calculated in the no action alternative is estimated to be 79% of the total dose.

- The two year temporary period is estimated to be 3% of the lifetime period used to calculate the total risk in the no action alternative.

When these two factors are combined, the total risk estimated for the temporary drinking water alternative is estimated to be 2% of the total lifetime risk for the no action alternative, for a net reduction of 98%. Risk associated with exposure to metals by ingestion is eliminated by the temporary drinking water alternative. Some risk may remain from dermal absorption of metals through continued contact with groundwater from domestic uses.

Alternative 2. Extension of the Elizabethtown Water Company supply system is a viable alternative for providing a drinking water that meets all criteria for protection of human health. The results of one water sample collected from the Elizabethtown Water Company supply system during the remedial investigation in 1986 indicate the presence of several indicator chemicals including chromium, lead, nickel and silver, however, additional samples collected in 1986 and 1987 by the NJDEP consistently complied with the New Jersey MCLs.

Alternative 4. The treatment system at a centralized community well would supply water which would meet all Federal and State requirements for the organic compounds included as indicator chemicals, minimizing the health risks. Air emissions from the treatment facility could result in exposure to nearby residents, however, an off-gas treatment system could be provided to eliminate this problem. In addition, it is unclear whether the metals concentrations would be reduced to levels below ARARs.

Environmental Assessment

General. None of the alternatives reviewed in this feasibility study address the issue of actually decontaminating the groundwater to reduce or eliminate the transport of contaminants. The purpose of groundwater treatment in alternative 4 is for the sole purpose of providing safe, potable water for domestic use for the residents in the area of concern. Therefore, the contaminated groundwater and the potential spread of contamination will remain an issue for each of the alternatives. The final feasibility study from the ongoing remedial investigation will address treatment of the groundwater plume at a later date.

Alternative 1. There are no adverse environmental impacts associated with the use of temporary water prior to the implementation of a permanent solution.

Alternative 2. The Montgomery Township Housing Development will experience no major adverse environmental impacts as a result of the expansion of the Elizabethtown Water Company supply system. Minor inconveniences due to the installation of water mains may occur, however, no other problems such as disruption of contaminated soil will occur since no contaminated soil has been identified in the housing development or along Montgomery Road, where construction will take place.

Alternative 4. Although treatment of the groundwater by the centralized community treatment system will remove contaminants to an acceptable level for

domestic use, this technology does not decontaminate and recharge the aquifer, as stated above.

The major adverse environmental impact of the treatment system is the discharge of volatile organics in the process off-gas. The air emissions of the treatment system would have to be evaluated, and appropriate design measures would have to be incorporated to ensure that air quality standards are met before implementation. A common method of treating off-gas from a stripping column of this size is by adsorption onto vapor-phase granular activated carbon, providing that the contaminants in the off-gas are amenable to carbon adsorption.

Assessment of Technical Feasibility

Alternative 1. The supplying of temporary drinking water from a local bottled water company is easily implemented. The annual cost of supplying 39 residents with bottled water includes an annual rental charge of $6,000 and a water charge of $53,000, for a total of $59,000 per year.

Alternative 2. With the expansion of the Elizabethtown Water Company's supply system, a safe and reliable means of supplying water to the affected residents will be provided. The extension of the existing distribution system, which would include extending the water mains and providing water service to the residents, is a technically feasible and economic solution for providing potable water. The capital cost for expanding the Elizabethtown water company is estimated at $319,000, as presented in Table 5-2. The expansion of these facilities could be implemented in a six (6) to nine (9) month period including design, approval and construction of the system. In addition to supplying water to the residents currently living in the area, future residential connections could be handled by the proposed distribution system.

Alternative 4. Installation of a centralized community well with a well water treatment system will be implemented using established technology and construction practices.

The reliability of the selected treatment system is based on the existing water quality and contaminants identified. Possible future variations of contaminant levels or newly identified contaminant parameters could adversely affect the reliability. Both treatment technologies would use equipment that is commercially available and has well documented histories of treatment efficiency in similar applications.

The planned treatment system design, construction and start-up could be implemented within a six (6) to twelve (12) month period after the facility has been set up as a state owned and operated utility for owner and operational considerations. Implementation of the centralized treatment system would also require time for property acquisition.

The establishment of the facility as a state owned and operated utility could take from a few months to over a year based upon the cooperation of the residents, the proposed owner (town or county) and State authorities. The time required to complete any necessary pilot studies and design, construct and start-up the treatment system would be likely longer than for Alternative 2, especially since land acquisition would also have to be accomplished.

Based on the individual contaminants found in the groundwater, the water treatment systems for Alternative 4 would meet all Federal and State requirements for organics. Pilot testing would be required to determine whether standards for metals would be met. Since low concentrations of metals are removed by activated carbon adsorption, it is possible that metals will be removed to an acceptable level, but this cannot be guaranteed at this point in time. The treatment system would achieve the established requirements by transfer of contaminants from the water to the air and by adsorption of any contaminants remaining after air stripping onto activated carbon. Air emissions for any of the treatment system considered would have to be evaluated.

The sizing of the treatment system for Alternative 4 has been established for the thirty-nine (39) contaminated residential wells. The centralized treatment

system could handle limited additional capacity for possible future housing by operational modifications and addition to the distribution network, however, larger increases would require modifications and/or expansions to the system components. It has been assumed that houses already connected to the Elizabethtown Water Distribution System will continue to use this water source.

The capital and O&M costs for the new community well and treatment system are presented in Table 5-3. Because of the use of disposable activated carbon cartridges, the annual operation and maintenance cost for carbon replacement is much higher than the initial capital cost for the carbon cartridges. However, the removal and disposal of the cartridges by the carbon vendor rather than removal and replacement of contaminated carbon on-site eliminates any risk of exposure to or spilling of the contaminated carbon.

COST EFFECTIVENESS ANALYSIS

The annualized cost analysis for each alternative provides a method of evaluating and comparing alternative capital and O&M costs over different selected project implementation periods. The capital costs include the cost of construction for the treatment facilities specified as well as the analytical costs associated with facility start-up and approval. The O&M costs include utility costs, analytical costs as well as replacement costs. No costs have been included for property acquisition or establishment of a state owned and operated utility. The total annualized cost of an alternative is composed of an annualized capital cost and an annual O&M cost. The annualized capital cost is based on an assumed annual interest rate (10 percent) and the number of years the alternative will be in operation. Because it is not certain how long selected remedy may be implemented, the annualized cost evaluation has considered a five (5), ten (10), and twenty (20) year project life to demonstrate the cost advantages of alternatives over the short-term and long-term.

The results of the annualized cost analysis presented in Table 5-4, show the Elizabethtown water system extension alternative has a significantly lower annualized cost when compared with the new community well and treatment system alternative over the five (5), ten (10), and twenty (20) year implementation periods considered. In part, this is due to the long-term O&M costs associated with the treatment system. Although no capital costs are associated with the no-action alternative, an annual O&M cost for continued well water monitoring has been included.

SUMMARY

In summary, three water supply alternatives were assessed for public health concerns, environmental concerns, technical feasibility and cost factors. The alternatives included temporary water supply for the residents of the 39 homes by means of bottled water delivery, extension of the Elizabethtown Water Company supply system and installation of a new community well with well water treatment. A no-action alternative was also considered. Table 5-5 presents a summary of each alternative with associated costs and comments regarding the alternatives' effectiveness.

TABLE 5-1. CAPITAL COSTS FOR THE EXTENSION OF ELIZABETHTOWN WATER CO. DISTRIBUTION SYSTEM - ALTERNATIVE 2

Cost Item	Cost, $ *
D.I. Pipe (8-in.)	140,000
Valves (5)	14,000
Well Sealing	39,000
Service Connections (39)	51,000
Pavement Repair	15,000
SUBTOTAL	259,000
Engineering and Contingencies (25%)	65,000
TOTAL CAPITAL COST	319,000

* Does not include tax impact costs of Elizabethtown Water Co. or street opening permit costs of Montgomery Township.

TABLE 5-2. CAPITAL AND O&M COSTS FOR COMMUNITY WELL AND TREATMENT SYSTEM - ALTERNATIVE 4

CAPITAL COST Cost Item	Cost, $ *
- Well sealing	$39,000
- Locating & drilling of well	50,000
- Pumphouse, including well pump, building and foundation	50,000
- Storage Tanks (2 tanks, 20,000 gal.)	24,000
- Packed Tower Aeration System	30,000
- Activated carbon system	4,000
- Disinfection	5,000
- Distribution pumps and standby generator	50,000
- Distribution Piping	147,000
- Service Connections (39 homes)	51,000
SUBTOTAL CAPITAL COST	450,000
- Analytical (start-up monitoring)	1,000
- Engineering and contingencies (40%)	180,000
- Instrumentation and controls (15%)	68,000
TOTAL CAPITAL COST	699,000

ANNUAL O&M COST	Cost, $ *
- Utility	800
- Labor (60 hr/month)	11,000
- Analytical	2,000
- Carbon replacement	17,000
TOTAL ANNUAL OPERATING COST	31,000

* Excludes costs associated with property acquisition, and permitting.

TABLE 5-3. ANNUALIZED COST ANALYSIS (IN DOLLARS, $)

Alternative	Capital Cost	Annualized Capital Cost[2] 5 Yr	Annualized Capital Cost[2] 10 Yr	Annualized Capital Cost[2] 20 Yr	Annual O&M Cost[3]	Total Annualized Cost[4] 5 Yr	Total Annualized Cost[4] 10 Yr	Total Annualized Cost[4] 20 Yr
Temporary Drinking Water	-	-	-	-	59,000	-	-	-
Extension of Elizabethtown Water Company Supply System	319,000	84,000	52,000	37,000	-	84,000	52,000	37,000
New Community Well with Treatment[1]	699,000	184,000	114,000	82,000	31,000	215,000	145,000	113,000
No Action Alternative	-	-	-	-	29,000	29,000	29,000	29,000

1. Costs presented do not include costs for property acquisition.
2. Costs presented are in June 1987 dollars
3. Costs are rounded off to the nearest $1,000.

-CONTAB5-3

TABLE 5-4. SUMMARY OF ALTERNATIVES

	Capital Cost	Annual O&M Cost	Annualized Total Over 10 Years	Comments
0 - No Action	0	$29,000	$29,000	- Does not address public health concerns.
2 - Extension of Elizabethtown Water Co. Distribution System	$319,000	-	52,000	- Addresses public health concerns. This alternative generally generally exceeds NJ State Standards. - Most technically feasible and environmentally sound.
4 - New Community Well with Well Water Treatment	699,000	31,000	145,000	- Will meet NJ ground water criteria for organics, but there is no assurance that metals will be removed to levels below ARARs. - Potential releases of volatile organics in off-gas may result in new exposures to residents. Off-gas treatment may need to be provided. - Requires time for formation of the facility as a state-owned and operated utility and for property acquisition prior to implementation.

-COMTAB5-3

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